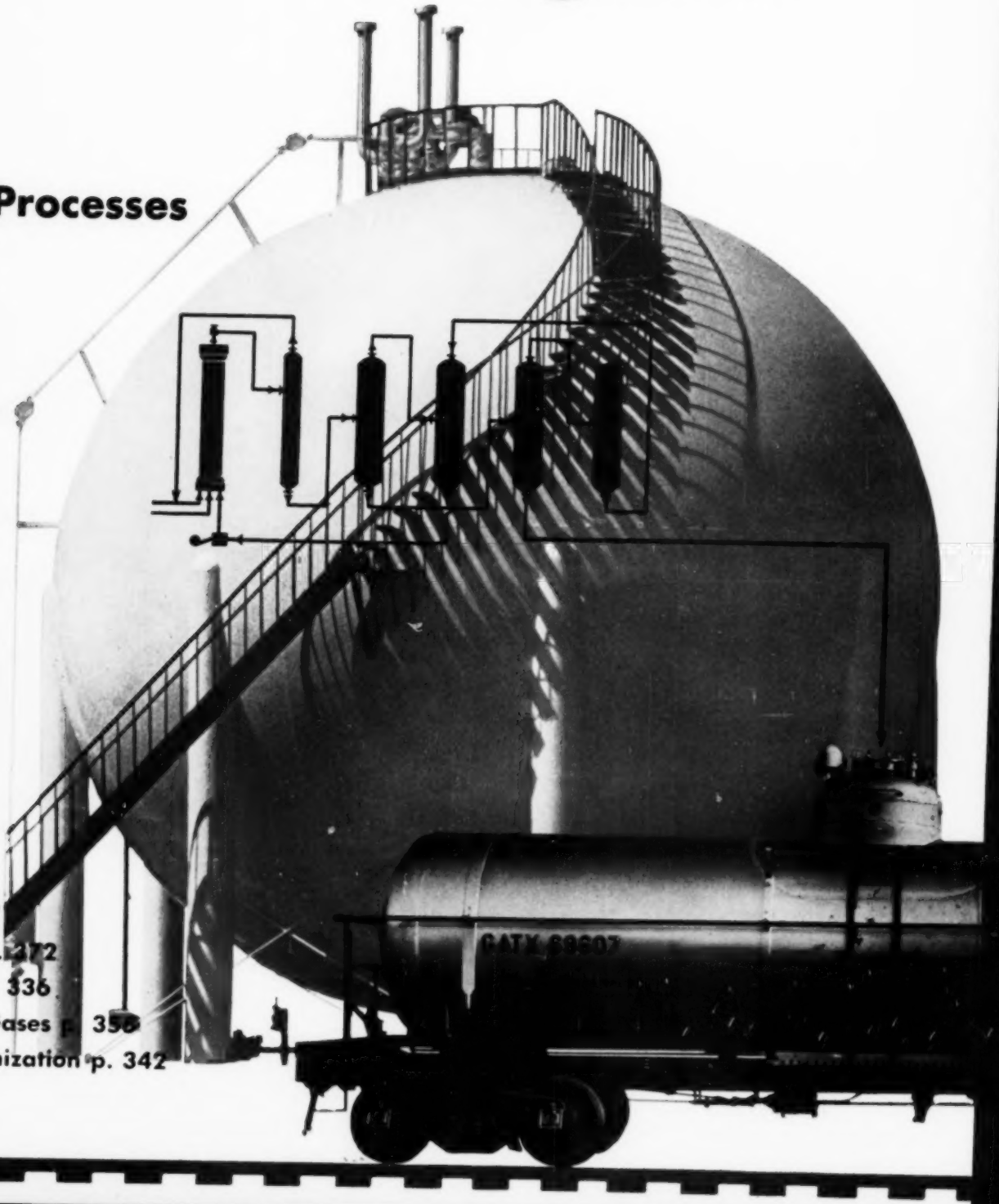
Chemical Engineering Progress

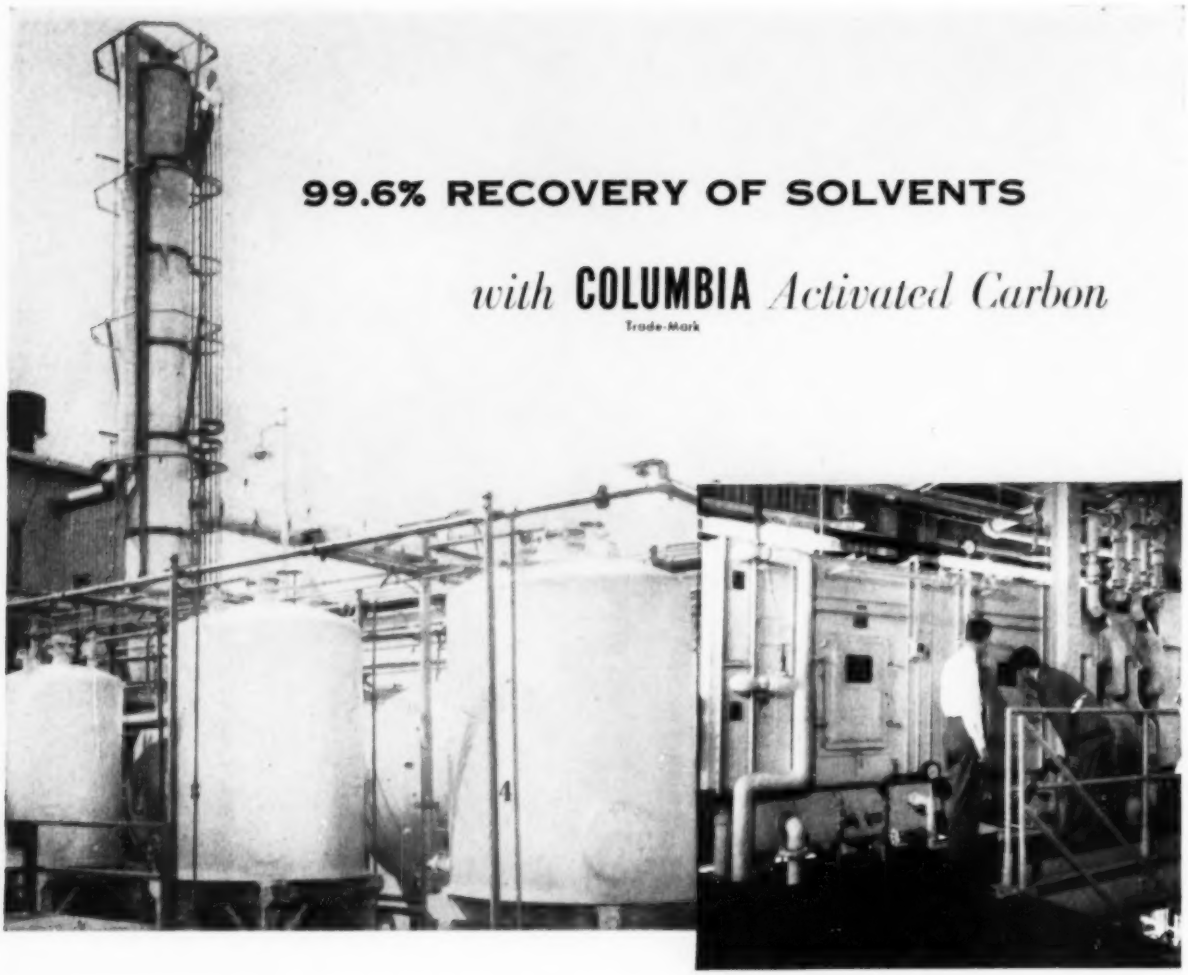
JULY 1954

New Processes



Urea p. 327
Acetylene p. 372
Shale Oil p. 336
CO_2 from Gases p. 356
Coal Carbonization p. 342

Nuclear Power: New Basis for Old Dilemma?—See National Meeting Report p. 35



99.6% RECOVERY OF SOLVENTS

with COLUMBIA *Activated Carbon*

Trade-Mark

Saves BAKELITE COMPANY $27,000 a month

This modern, CARBIDE-designed solvent recovery system in this plastics plant at Bound Brook, New Jersey, collects more than 600 pounds of solvent vapors an hour from the manufacture of BAKELITE vinyl cast film. It separates the solvents and delivers them ready for re-use—with a recovery plant efficiency of 99.6% and a cost of 1.5¢ per pound.

Two important features are behind this efficient, economical recovery. First, COLUMBIA Activated Carbon, with its long life and high adsorptive capacity for practically any low-boiling solvent. Second, the recovery plant, which was specially designed by CARBIDE's trained, experienced engineers to fit BAKELITE's recovery conditions.

All installations made by CARBIDE engineers are based upon careful surveys of the particular vaporization process. If the recovery problem is unusual, it is worked out on a pilot-plant scale. Then, the complete operating system is designed, supplied, and guaranteed by CARBIDE. Every recommended installation has paid for itself within a few years.

COLUMBIA Activated Carbon solvent recovery plants in use today save industry more than $150,000,000 a year by recovering over *two billion* pounds of solvents!

Write today for the booklet, "Solvent Recovery by the COLUMBIA Activated Carbon System" (Form 4110). In Canada: Carbide Chemicals Sales Company, Division of Union Carbide Canada Limited, Toronto.

CARBIDE AND CARBON CHEMICALS

COLUMBIA *Activated Carbon*

Carbide and Carbon Chemicals Company
A Division of
Union Carbide and Carbon Corporation
30 East 42nd Street UCC New York 17, N. Y.

"Columbia" and "Bakelite" are registered trademarks of Union Carbide and Carbon Corporation.

JULY, 1954

Volume 50, No. 7

Editor: F. J. Van Antwerpen

OPINION AND COMMENT

325 THE YOUNG AT HEART • GRASS ROOTS • WELCOME TO A NEW EDITOR

ENGINEERING SECTION

327 UREA—The new Chemico process
L. H. Cook

332 CENSUS OF EQUIPMENT SCALE-UP PRACTICE
Laurent Michel, R. D. Beattie, and T. H. Goodgame

336 OIL FROM SHALE
R. J. Cameron and Boyd Guthrie

342 ECONOMICS OF COAL CARBONIZATION
R. G. Minet, H. B. Smith, Jr., and C. A. Trilling

347 FLUIDIZED BED HEAT TRANSFER
W. W. Wamsley and L. N. Johanson

356 CO_2 ABSORPTION employing hot potassium carbonate solutions
H. E. Benson, J. H. Field, and R. M. Jimeson

365 ENGINEERS CAN WRITE BETTER Part III
H. J. Tichy

372 RECENT DEVELOPMENTS IN WULFF ACETYLENE
M. J. P. Bogart and R. H. Dodd

376 CAST HEAT ALLOY REFERENCE SHEET
N. S. Mott

NEWS AND FEATURES

33 PREVIEW: THE TRAIL LEADS TO COLORADO

35 NATIONAL MEETING REPORT: ANN ARBOR—Part I

40 INDUSTRIAL NEWS

44 OPERATION S.P.P.
Irving Leibson and A. G. Cocoso

52 A.I.Ch.E. CANDIDATES

55 DATA SERVICE

66 AUDITOR'S REPORT

70 FUTURE MEETINGS

71 NEWS OF THE FIELD from Local Sections

72 SOMETHING'S FISHY IN BOSTON!
A. W. Fisher, Jr.

76 NEWS ABOUT PEOPLE

82 CLASSIFIED

84 NECROLOGY

86 A.I.Ch.E. NEWS AND NOTES

6 LETTER TO THE EDITOR

6 • 10 • 14 NOTED AND QUOTED

24 • 27 • 29 MARGINAL NOTES

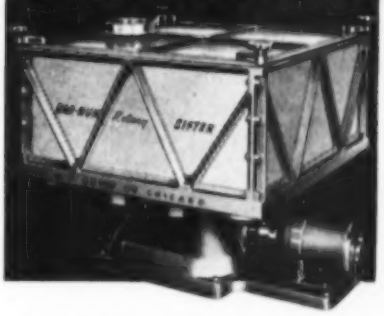
Advertising Manager: L. T. Dupree

THIS MONTH'S COVER

The theme is new processes. Chemical engineers will hardly need to have explained that the raw material is stored in the large Hortonsphere (photo courtesy of National Distillers Products Corporation—from their Tuscola plant). From there, it goes as indicated in the hypothetical flowsheet. The connection with the tank car is so obvious that nothing further need be said except that the photo is through the courtesy of General American Transportation Corporation. Titles of articles relating to the design theme are listed on the cover.

Published monthly by American Institute of Chemical Engineers, at 15 North Seventh Street, Philadelphia 6, Pennsylvania. Editorial and Advertising Offices 120 East 41st Street, New York 17, N. Y. Communications should be sent to the Editor. Statements and opinions in *Chemical Engineering Progress* are those of the contributors, and the American Institute of Chemical Engineers assumes no responsibility for them. Subscriptions: U. S. and possessions, one year $6.00; two years $10.00 (Applies to U. S. and possessions only.) Canada $6.50; Pan American Union, $7.50; Other Foreign, $8.00 Single Copies of *Chemical Engineering Progress* older than one year cost $1.00 a copy; others are 75 cents. Entered as second class matter December 9, 1946, at the Post Office at Philadelphia, Pennsylvania, under Act of August 24, 1912. Copyright 1954 by American Institute of Chemical Engineers. Member of Audit Bureau of Circulations. *Chemical Engineering Progress* is indexed regularly by Engineering Index, Inc.

Better Sifting
Better Grading
OF DRY MATERIALS



BAR-NUN
all-metal Rotary Sifter
GIVES

- Clean, Thorough Separations
- Big Capacity in Small Floor Space
- Dust-tight, Sanitary Operation

The Bar-Nun Rotary Sifter is a compact, self-contained, motor-driven unit for making particle-size separations on most all dry, powdered, granular, flaked or crystalline materials. The smooth, vibrationless operation requires less power and contributes to long life and low maintenance cost, even in continuous 24-hour service. Minimum floor space and head room are required.

A new and exclusive four-point drive with mechanically controlled, single-plane rotary motion over the entire screen area increases the yield of clean, accurate separations per square foot of sieve area. No rods or flexible supports are required to carry the all-metal sifter box which is dust-tight, and easily opened for inspection and cleaning or for removal of sieves.

The operating advantages of Bar-Nun Rotary Sifters have been proved in actual daily production in many process plants and users claim outstanding operating economies as well as trouble-free, continuous service.

Available in several standard sizes with one to four sieves for two or more separations. Location of outlets optional to meet plant material flow preferences. A choice of sieves and sieve frames available to meet a variety of conditions and requirements.

Complete Information and Recommendations for any Sifting or Grading Job on Request

5195

B. F. GUMP CO.
Engineers and Manufacturers Since 1872
1311 S. Cicero Ave.
Chicago 50, Ill.

Here's How To Hold On

ROCKWELL-Nordstrom

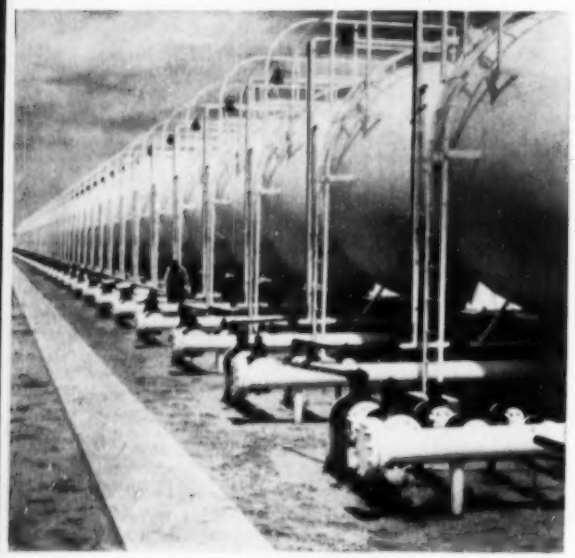
It takes a really efficient valve to hold light ends and petrochemicals. Rockwell-Nordstroms are the ideal valves for these services because they assure positive, dependable control with a minimum of maintenance.

A pressurized lubricant film between the valve plug and the body seals even the lightest hydrocarbons and eliminates uncertain metal-to-metal closure.

Pressurized lubrication also eliminates metal-to-metal friction on the working surfaces which means long-term economy in the maintenance of the hundreds of valves used in each refining and petrochemical operation. Less wear means less care and replacement . . . lower costs.

Rockwell-Nordstrom valves are manufactured in sizes through 30 in. Certain sizes are available in pressure ratings of 10,000 lb WOG.

Find out how Rockwell-Nordstrom valves

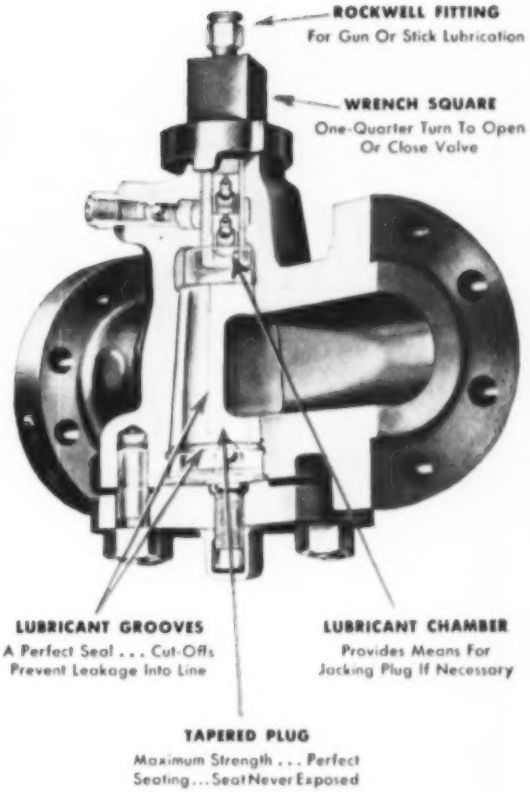


BUTANE STORAGE The Rockwell-Nordstrom valves on these butane storage tanks provide "no leak" service whether operated once a month or once every hour. Valve wrenches tell at a glance if the valve is open or closed.

FRACTIONATING These Rockwell-Nordstrom plug valves on a light ends fractionating unit can really be depended upon to do the job. Pressure lubrication keeps them ready for instant operation.

To Light Ends

VALVES

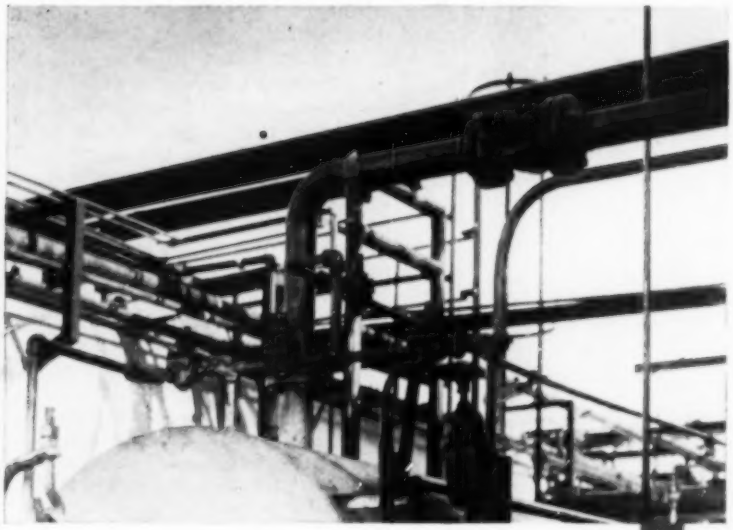

ROCKWELL FITTING
For Gun Or Stick Lubrication
WRENCH SQUARE
One-Quarter Turn To Open Or Close Valve
LUBRICANT GROOVES
A Perfect Seal . . . Cut-Offs Prevent Leakage Into Line
LUBRICANT CHAMBER
Provides Means For Jacking Plug If Necessary
TAPERED PLUG
Maximum Strength . . . Perfect Seating . . . Seat Never Exposed

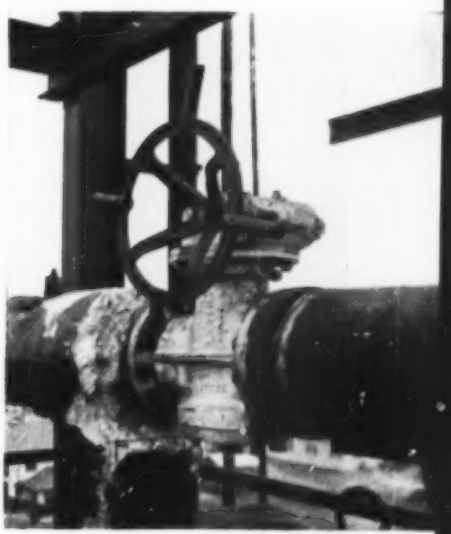
can give you better service, greater efficiency, and lower operating cost than any other valve you've ever used. Write today to Rockwell Manufacturing Company, Pittsburgh 8, Pa. *Canadian Valve Licensee:* Peacock Brothers Limited.

ROCKWELL-Nordstrom **VALVES**

Lubricant-Sealed for Positive Shut-Off

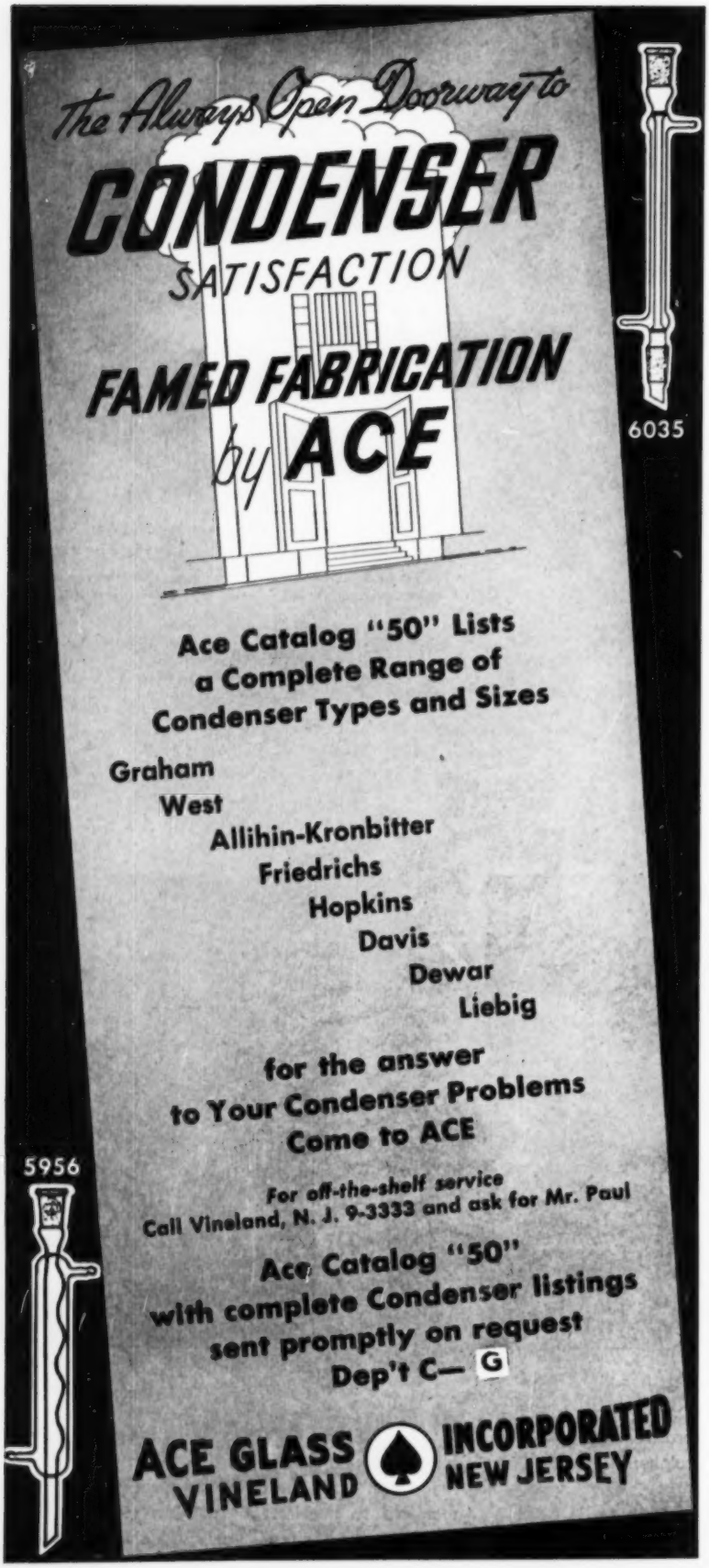
ANOTHER PRODUCT



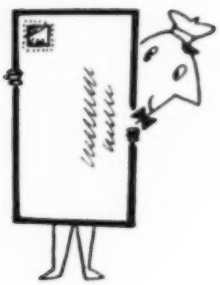


ALKYLATION UNIT Rockwell-Nordstrom valves handle *both* the light ends and the sulphuric acid in an alkylation unit.

POLYMERIZATION UNITS For really tough service this 6 in. hard faced Hypreseal is *the* valve. Used here on the process header manifold to the inlet of catalyst tower on a polymerization unit, this valve will give long-life, trouble-free service.



Letter to Editor



Congratulations on the May issue of Chemical Engineering Progress. It's really quite a feather in the cap of A.I.Ch.E.

State College, Pa. ARTHUR ROSE

Chemotherapy and the Diseased Mind

The day is coming, is here in certain minor ways, when chemical control of mental disease may be a powerful weapon in the war against man's ills. It could empty many, perhaps most, of the hospital beds of the country devoted to diseases of the mind. This is in some ways far more important than the attack on cancer and heart disease, more important even than geriatrics, for sound mental and emotional life, happy constructive life, is far more important than mere length of years. True, we would press every effort to remove pain and distress; the modern approach to narcotics is, for example, a very salutary thing; but solution of the problem of the mentally unhinged, by chemotherapy and in other ways, opens up still more attractive vistas. Still, we should not overlook the fact that chemical control of mental disease also implies chemical control of the emotions, and that this can have its appalling dangers. We had best have our governmental systems in very stable form indeed before such things become possible. A world in which chemical additives to the diet would produce docility, or the reverse, may produce problems beside which control of atomic energy is relatively simple.

Vannevar Bush
Speech at Stamford Research Institute

(More Noted and Quoted on page 10)

Lapp Valves are Solid Porcelain

You need to make no compromise with contamination or corrosion from valves in chemical processing. Lapp valves are of *solid* Lapp Porcelain, a material unique as a ceramic for industrial scale chemical service. It alone offers the following combination of characteristics and qualities:

PURITY • Lapp Porcelain is a potassium aluminum silicate, made from selected clays, flint and feldspar...has no free iron or other metallic impurity.

NON-POROUS • Complete vitrification of all sections, through firing to 2300°F., provides *zero* porosity. No dye penetration of body in 100,000 psi test. No chemical can penetrate in service.

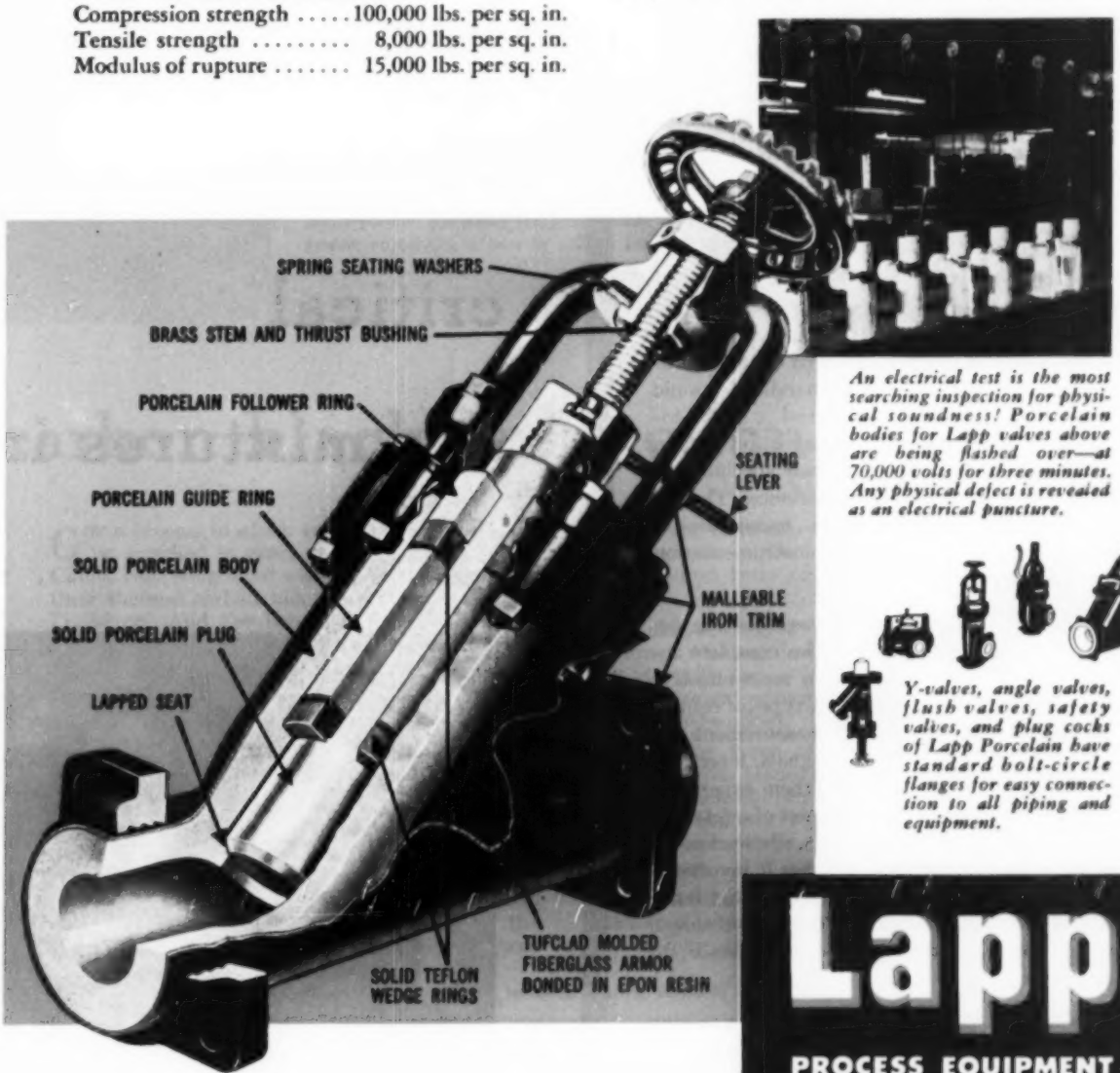
HIGH MECHANICAL STRENGTH

Compression strength	100,000 lbs. per sq. in.
Tensile strength	8,000 lbs. per sq. in.
Modulus of rupture	15,000 lbs. per sq. in.

CHEMICAL RESISTANCE • Lapp Porcelain is unaffected by any acids except HF. It provides years of trouble-free service, handling hot acids in all concentrations, as well as mixed acids and other troublesome combinations.

UNIFORM QUALITY • Lapp Porcelain has been manufactured for 38 years for use in most severe chemical, electrical and mechanical services. Plant facilities include Lapp-patented vacuum processing, deaerating pug mills, two continuous tunnel kilns, and complete chemical, electrical and mechanical test equipment.

Write for bulletin with complete description, characteristics, and specifications. Lapp Insulator Co., Inc., Process Equipment Division, 334 Wendell St., LeRoy, N. Y.



An electrical test is the most searching inspection for physical soundness! Porcelain bodies for Lapp valves above are being flashed over—at 70,000 volts for three minutes. Any physical defect is revealed as an electrical puncture.

Y-valves, angle valves, flush valves, safety valves, and plug cocks of Lapp Porcelain have standard bolt-circle flanges for easy connection to all piping and equipment.

Lapp

PROCESS EQUIPMENT

Chemical Porcelain Valves • Pipe • Raschig Rings
Pulsafeeder Chemical Proportioning Pumps

There's more to instrumentation than instruments

Instruments can do wonders, if they're given the chance. But some one has to put them to work in the most effective way. And that's where Honeywell Application Engineering steps in.

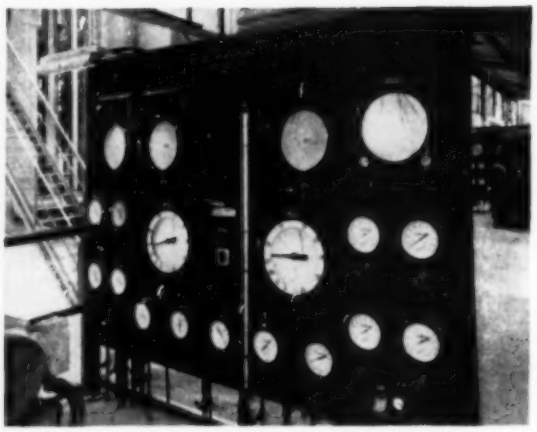
This service is one of the most important plus values you get in Honeywell instrumentation. It's a teamwork job. And every member of the team is an expert in his own field. Engineering begins right in your own plant, where a Honeywell field man digs out the vital facts about your process. He sits down with your engineers, production men and instrument technicians . . . and finds out everything he needs to know about what needs to be measured or controlled, to what accuracy, and under what conditions.

Then the problem goes to Honeywell's Application Engineering staff. Here's where you'll find groups of instrumentation specialists for every major industry. One group, for example, is devoted to the control problems of the metalworking industry. Another handles ceramic applications . . . another chemical . . . until together they cover the whole gamut of modern processes. These men know their specific field from years of first-hand experience. They're thoroughly familiar with the techniques of processing and the ways that instrumentation should be applied.

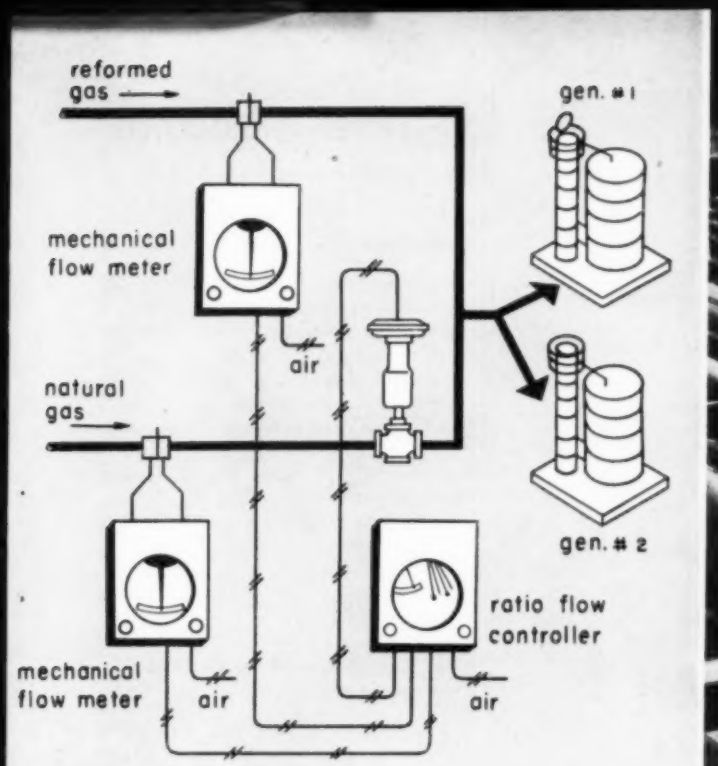
Honeywell Application Engineers develop detailed recommendations for the complete installation. They determine the most effective instruments, primary elements, types of control and valves for every phase of measurement and control. They add switches, signals, interlocks and other accessories which their experience indicates are needed in the interest of safety and convenience. Then they combine all components into a complete system—whether it involves a single instrument or a whole panel—that is designed for peak production efficiency, simple maintenance, and greatest convenience to operators.

This service saves time by doing engineering work that would tie up your own staff for many hours. And it pays off in assuring the excellent performance of which Honeywell instruments are capable.

Ratio controller regulates critical gas mixtures in



Control panel for carbon black generators includes (in upper right corner) Brown ratio flow controller . . . along with ***ElectroniK*** *instruments for checking temperatures inside the generators.*



Brown flow transmitters are mounted outdoors, next to natural gas and reformed gas lines. Diagram shows the complete ratio control system supplying a pair of carbon black generators.

carbon black production

Got a process in which two different gases must be supplied in exact proportion? Godfrey L. Cabot, Inc., were faced with a problem like this in their thermal carbon black plant near Franklin, Louisiana. And the Brown flow control system that was developed for this job in cooperation with The Gas Machinery Company may give you some ideas for your own applications.

The Cabot process cracks carbon out of natural gas, in cyclic reactors or generators designed and built by The Gas Machinery Co. To produce various grades of black, the natural gas fed to the generators must be diluted with reformed gas. A Brown two-pen ratio flow controller, working with two Brown mechanical flow meters, does the trick. The flow meters measure the flow in both the natural and reformed gas lines, and each transmits air pressure signals to actuate one of the ratio controller's pens. On the basis of these signals, the controller regulates a Honeywell diaphragm valve in the natural gas line, to maintain the required ratio of flows of natural gas and diluent.

This simple, rugged system provides excellent accuracy, to keep flow ratios at optimum values. It's versatile, too . . . can be readily set to allow feed of straight natural gas when coarse grades of carbon are required.

Many other types of flow instrumentation are available from Honeywell for the varied requirements of chemical processes. Your nearby Honeywell field engineer will be glad to discuss your specific applications . . . and he's as near as your phone.

Minneapolis-Honeywell Regulator Co., *Industrial Division*, Wayne and Windrim Avenues, Philadelphia 44, Pa.

● **REFERENCE DATA:** Write for new Catalog 2320, "Flow Meters, Indicating, Recording, Integrating and Controlling."

MINNEAPOLIS
Honeywell
BROWN INSTRUMENTS
First in Controls

Complete your Library of Cost-Cutting Ideas

• Write for these three new catalogs

Chemiseal Gaskets and Accessories • Bulletin TG-953

Corrosion Resistant TEFLON Jacketed Gaskets for glass-lined steel connections, Corning conical flanges, etc. Chemiseal molded TEFLON Snap-on Gaskets for conical-end glass pipe assuring automatic centering of joints and free flow of materials. Chemiseal Adaptors which provide a safe, tight seal between conical-end glass pipe, glass-coated steel or similar nozzles of large inside radii and vessels of glass-lined steel, porcelain, Haveg, etc.

Chemiseal Valve and Pump Packings • Bulletin TP-1053

V-Rings, Cup and Cone, and Wedge Type Packings of Chemical resistant pure TEFLON—engineered for greater flexibility and resiliency—providing necessary seal with low gland pressure, reducing torque required to operate valves. Pump packings of pure TEFLON or TEFLON impregnated with Graphite or with Mica for chemical resistant, non-contaminating service throughout the processing industries.

Chemiseal Expansion Joints and Flexible Couplings • Bulletin FC-952

Absorb shock, vibration, thermal expansion and contraction. Correct misalignment. Connect unlike piping ends and nozzles. Chemical resistant TEFLON Bellows with integral TEFLON Gaskets.

UNITED STATES GASKET COMPANY

CAMDEN 1 • NEW JERSEY

FABRICATORS OF duPont TEFLON
Kellogg KEL-F AND OTHER PLASTICS

Representatives in Principal Cities Throughout the World

NOTED AND QUOTED

(Continued from page 6)

Radioactivity

Coloured modifications of normally colourless crystals, such as those of rock-salt and fluorspar, are occasionally found in nature. The coloration appears to be conditioned by the presence of irregularities in the crystal lattice. Similar effects may be produced by exposing the crystals to radiation, and there is a good deal of evidence, both qualitative and quantitative, that this is also the process by which the minerals become coloured naturally.

Karl Przibram
Endeavour

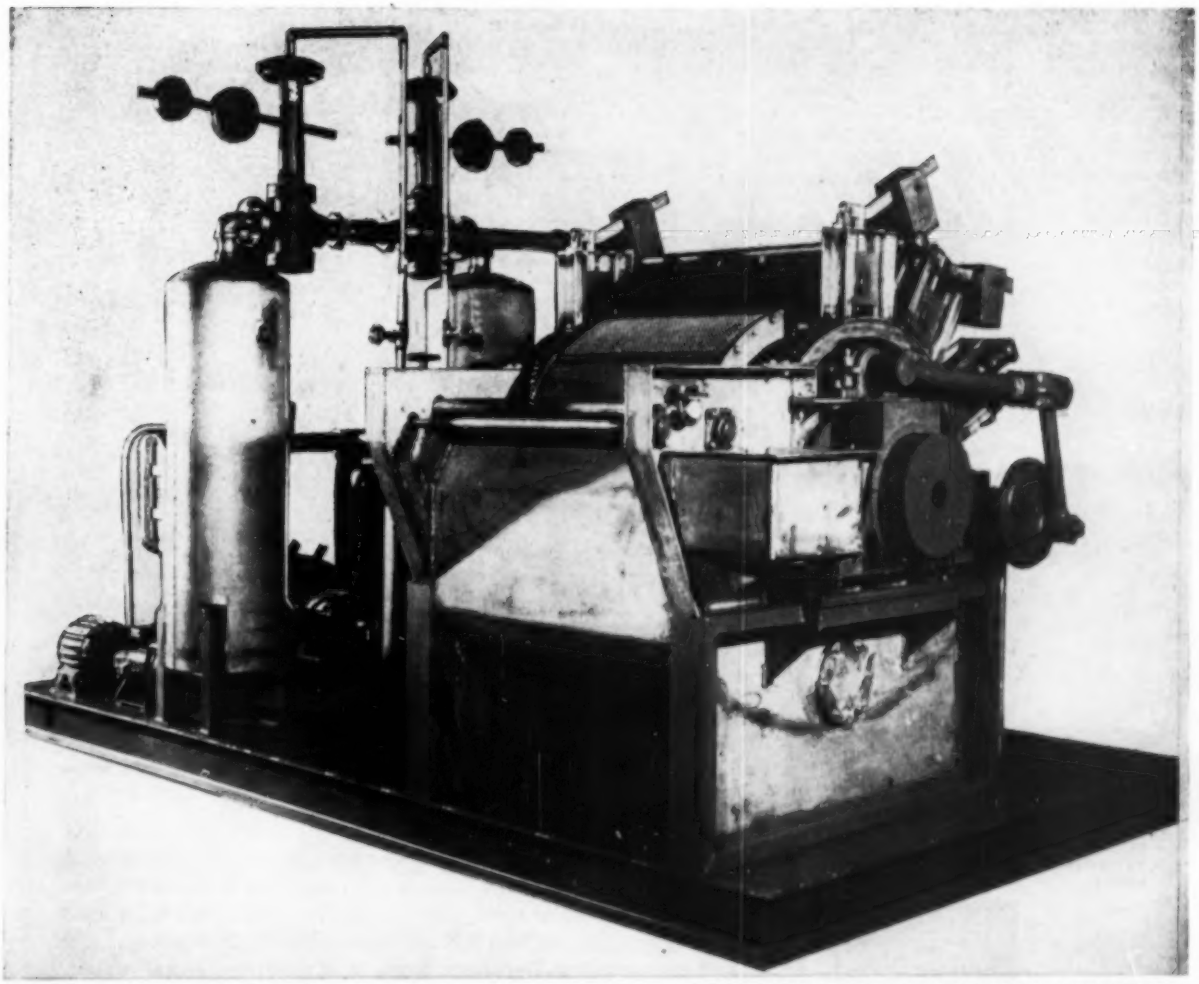
That Capable and Cultivated Human Being

The purpose of the liberal arts is not to teach businessmen business, or grammarians grammar, or college students Greek and Latin (which have disappeared from their required curricula). It is to awaken and develop the intellectual and spiritual powers in the individual before he enters upon his chosen career so that he may bring to that career the greatest possible assets of intelligence, resourcefulness, judgment, and character. It is, in John Stuart Mill's telling phrase, to make "capable and cultivated human beings." "Men are men," Mill said, "before they are lawyers or physicians or manufacturers; and if you make them capable and sensible men they will make themselves capable and sensible lawyers or physicians." . . .

From this statement we may proceed . . . to the conclusion that the liberal arts and many of the studies thought to be in competition with them are not competitors but allies. This was Mill's pronouncement on the conflict that raged in his day between the "old classical studies" and the "new scientific studies." . . .

There is even less reason for such a conflict of principles today. The "old classical studies" have been greatly enriched by the infusion of history, philosophy, literature, language, and the fine arts. . . . Scientific studies never were "new" to the liberal arts, as they claimed three of the original seven. The very term "liberal arts" has given way in professional academic usage to the term "general education," with its obviously broader implications as to content and method. Every trade, profes-

(Continued on page 14)



HIGH SUBMERGENCE STRING DISCHARGE CONTINUOUS VACUUM FILTERS

Industries using standard design drum and disc type continuous vacuum filters are often interested in a specialized Eimco filter to develop a new product, increase production or complete a research project.

Such was the case of the customer who ordered the machine shown above. It is a high submergence (55%) stainless steel drum type filter equipped with compression rolls, string discharge and wash headers.

This unit uses Eimco "pin" type agitator and the vacuum line is equipped with vacuum regulating valves. All necessary operating equipment including receivers, motors, pumps, etc., are mounted in standard Eimco package arrangement on a fabricated steel sub-base with piping in place and wiring to a control panel.

Call an Eimco Engineer and let him help you solve your filtration problems (no obligation to you). Eimco has been serving the processing industries for more than half a century.

THE EIMCO CORPORATION

Salt Lake City, Utah—U.S.A. • Export Offices: Eimco Bldg., 52 South St., New York City

New York, N. Y. Chicago, Ill. San Francisco, Calif. El Paso, Texas Birmingham, Ala. Duluth, Minn. Kellogg, Ida. London, Eng. Paris, France Milan, Italy

You Can't Beat An Eimco

Acetate Solvents, Crude
Acetate Solvents, Pure
Acetic Acid
Acetic Anhydride
Acetone
Acetylene, 15 psi
Air
Alcohols
Aluminum Ch
Aluminum P
Aluminum
Aluminu
Alums
Ammonia Gas
Ammonia Liquors
Ammonium Bisulfite (above 7.0 pH)
Ammonium Carbonate
Ammonium Chloride
Ammonium Hydroxide
Barium Cyanide
Barium Hydroxide
Bari

Carbon Dioxide, Dry
Carbon Dioxide, Wet
Carbonic Acid, Carbonated Beverages
Chromic Acid
Chromium Potassium Sulfate
Citric Acid
Coke Oven Gas
Cop
Creosote
Cresylic Acid
Solutions
dehyde
cid

Hydrogen Gas
Hydrogen Peroxide
Hydrogen Sulfide
Iron Chloride (Ferric)
Iron Chloride (Ferrous)
Iron Potassium Sulfate (Ferric Alum)
Iron Sulfate (Ferric)
Magnesium Chloride
Magnesium Hydroxide
Magnesium Sulfate
Magnesium Sulfite
Mercuric Chloride
Oxalic Acid
Petroleum Oils, Refined
Phenol (Carbolic Acid)
Phosphoric Acid
Acid, Aqueous

Sulfuric Acid
Sulfurous Acid
Tartaric Acid
Tin Chloride (Stannic)
Tin Chloride (Stannous)
Sulfate (Stannic)
Sulfate (Stannous)
Water, Acid Mine Waters
Water, Boiler Feed
Water, Distilled, Laboratory Grade
Water, Distilled, Return Condensate
Water, Fresh, Industrial Supplies
Water, Saline, Sea Water, etc.
Zinc Chloride

Name your poison

or any hard-to-handle fluid

WORKING PRESSURES—up to 150 pounds, water, air, oil, or gas, 250°F. maximum temperature, depending on valve size, materials, and service.

CRANE HAS THE BETTER VALVE FOR IT!

Better because they're safer, easier to operate. *Better* because they reduce maintenance to a negligible degree. And that holds true for just about any service, any fluid within rated pressure and temperature.

For Crane now offers the revolutionary diaphragm valve in a new wide choice of body, disc insert and diaphragm materials—in unlined or lined patterns. You specify whatever combination best suits your particular need. The regular line-up includes brass, cast iron, aluminum, or 18-8 SMo body and disc . . . with diaphragm and disc insert of Neoprene, Buna N, Kel -F, or natural rubber. Regular linings are Neoprene or hard natural rubber. Also sliding stem valves for automatic operators of all types. In addition, Crane Diaphragm Valves are regularly available for high-vacuum service, or oxygen and acetylene usage. Other body and disc materials, as well as linings, available on special order. Sizes from ½ to 6-inch.

HOW CRANE DIAPHRAGM VALVES WORK

The Crane diaphragm serves one function only—sealing the bonnet. It is not subject to crushing and rapid wear. The seating member is a separate circular flat face disc, firmly attached to the stem and joined to the diaphragm with a special leak-proof connection. This independent seating feature permits positive shut-off with no loss of fluid, even in case of diaphragm failure.

NEW LITERATURE . . . NEW FILM

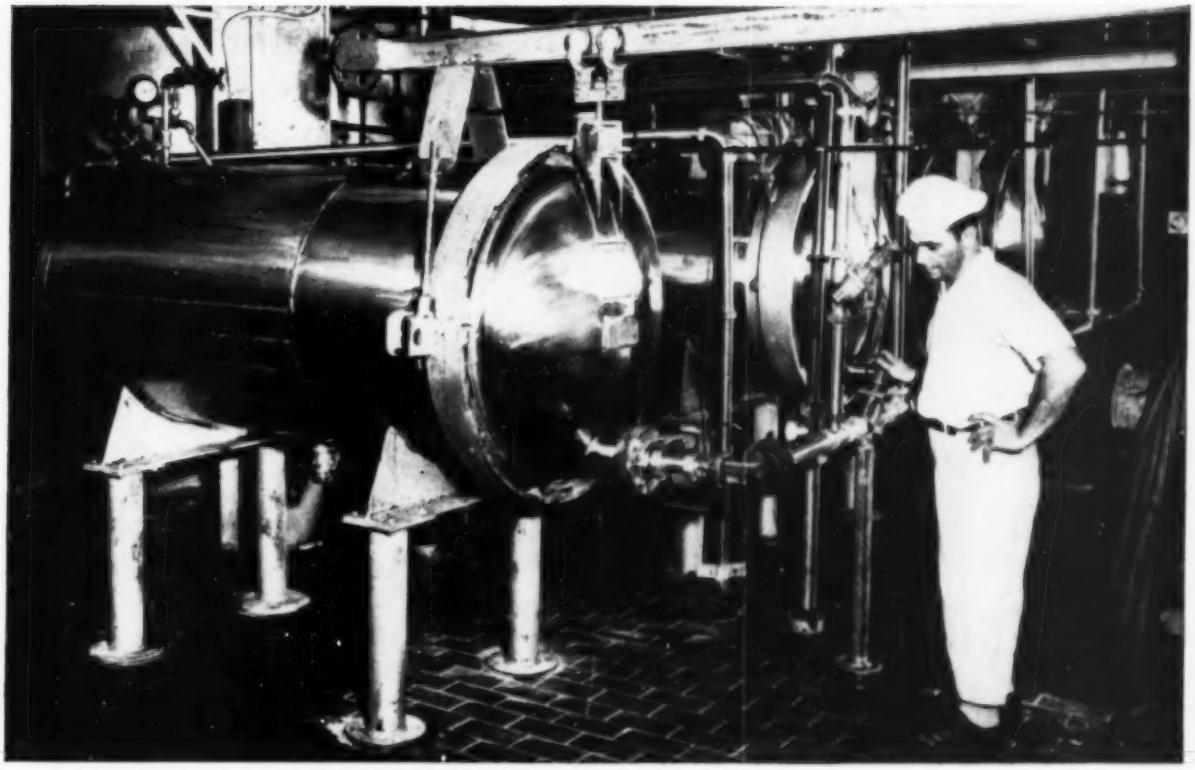
Get complete, interesting facts about the expanded line of Crane Packless Diaphragm Valves in a new 24-page folder . . . and a new sound movie. You'll see how this revolutionary valve solves flow control problems where others fail. Check with your local Crane Representative, or use the coupon below.

CRANE CO., 836 S. Michigan Ave., Chicago 5, Illinois
Gentlemen:
I would like to arrange for a free showing of the Crane Diaphragm Valve Film ( ).
I would like a copy of Diaphragm Valve Folder ( ).
Name .....
Company .....
Address .....
City .....Zone.....State .....

CRANE CO.

General Offices: 836 S. Michigan Ave., Chicago 5, Ill.
Branches and Wholesalers Serving All Industrial Areas

VALVES • FITTINGS • PIPE • PLUMBING • HEATING



1 MAN does the work of 3 with this efficient horizontal filter

One man can easily operate several Niagara Horizontal Filters . . . producing as much as three men operating old fashioned filter presses.

Here's why: A Niagara Horizontal will filter to clarity at rates up to 45,000 G.P.H. Flow rates are two to five times greater than those of old style cloth covered presses. A Niagara can be taken off stream, drained, opened, cleaned, closed, filled and precoated . . . by one man . . . in a matter of minutes, not hours. And there's no time lost installing cloths . . . no cloth washing . . . no cloth expense.

Result . . . maximum filtration efficiency . . . greatly reduced operating time . . . minimum downtime . . . with costs reduced in proportion.

When you have a combination like this . . . improved filtration, faster, for less money . . . it's easy to see why your Niagara Horizontal Filter will quickly pay its entire cost through direct savings. Ask any of the hundreds of Niagara users. You'll get the same story.

Niagara Filters, both horizontal and vertical, are available in a wide range of capacities and can be made of stainless steel or other alloys for corrosion resistance. And Niagara users are served by filtration specialists located in 27 cities from coast to coast.

Want details? Just clip and mail the coupon.

NIAGARA ENGINEERS ARE FILTRATION SPECIALISTS

They've had years of experience. They'll study and analyze your filtration problems . . . test your samples . . . pilot the filtration . . . and build a Niagara unit to meet your most exacting requirements.

Niagara Filters
DIVISION
AMERICAN MACHINE AND METALS, INC.
DEPT. CEP754, EAST MOLINE, ILLINOIS

In Europe: Niagara Filters Europe, Post Box 1109, Amsterdam-C, Holland

YES . . . we'd like to know more about Niagara Pressure Leaf Filters for _____

☐ Have representative call ☐ Send new catalog NC-1-53

Name _____

Title _____

Company _____

Address _____

City _____ Zone ____ State _____

your concrete floors with PHENOLINE 300

CORROSION RESISTANT COATING

- ***Highly resistant to acids, alkalies, solvents***
- ***100% solids—no special ventilation required during application***
- ***Can be applied over any type flooring—new or old concrete, asphalt, brick and wood***
- ***Fast thermo-setting—no baking required***
- ***Easy to wash down and keep clean***
- ***Protects against back-pressure and seepage***
- ***Can be troweled, brushed or sprayed***
- ***Available in any color***

Floors pitted and worn by corrosives are not only unsafe, but are especially hard to clean and maintain. Phenoline 300 is designed to keep your floors in a sound condition by providing an effective, impermeable barrier against most acids, alkalies and solvents.

What is your corrosion problem?

Write giving us complete details on the corrosive conditions damaging your floors. We will be happy to suggest the Phenoline 300 application best suited to your needs.

carboline COMPANY

A Division of Mullins Non-Ferrous Castings Corporation

Specialists in Corrosion Resisting Synthetic Materials

335 Thornton Ave., St. Louis 19, Mo.

NOTED AND QUOTED

(Continued from page 10)

sion, and vocation has an equal interest in "capable and cultivated human beings." How could this represent a conflict of principle?

A. Whitney Griswold
The Free Economy of Students
Saturday Review of Literature

Two Minds, One Idea

It often happens that two or more persons, working entirely independently of each other, may make the same invention. Since a patent may be granted only to the first inventor, when two or more applications embodying such an invention are co-pending, . . . an *interference* is declared and a definite procedure . . . is followed to determine the first inventor.

The burden of the proof is on the inventor whose application was filed last. If the inventor who filed last was the first to conceive the invention, . . . he must prove that he worked diligently towards reducing his invention to practice from the time just prior to the conception date of the other invention until his own invention was either physically reduced to practice or until his application was filed. . . . Hence, if the inventor whose application was filed last is unable to prove such diligence then the other party will be awarded the patent even though his conception of the invention was later. It, therefore, is important to exercise the utmost diligence in completing the invention. . . .

The line of demarcation between invention and non-invention often is difficult to ascertain. Generally speaking, if the new device produces a new result or an old result in a new or more efficient manner, it is regarded as involving invention and may be patented.

Carl F. Sibbe
In General Motors Engineering Journal

Modern Galley Slaves

The technologist has kept pace with the bureaucrat and the social reformer. Every man, woman and child in America has at his disposal 280 horsepower hours of energy per day, or the equivalent of some 500 galley slaves of the Roman Empire period.

P. D. Foote
Gulf Oil Research Head

(Marginal Notes on page 24)

MARLEY SINGLE-FLOWS

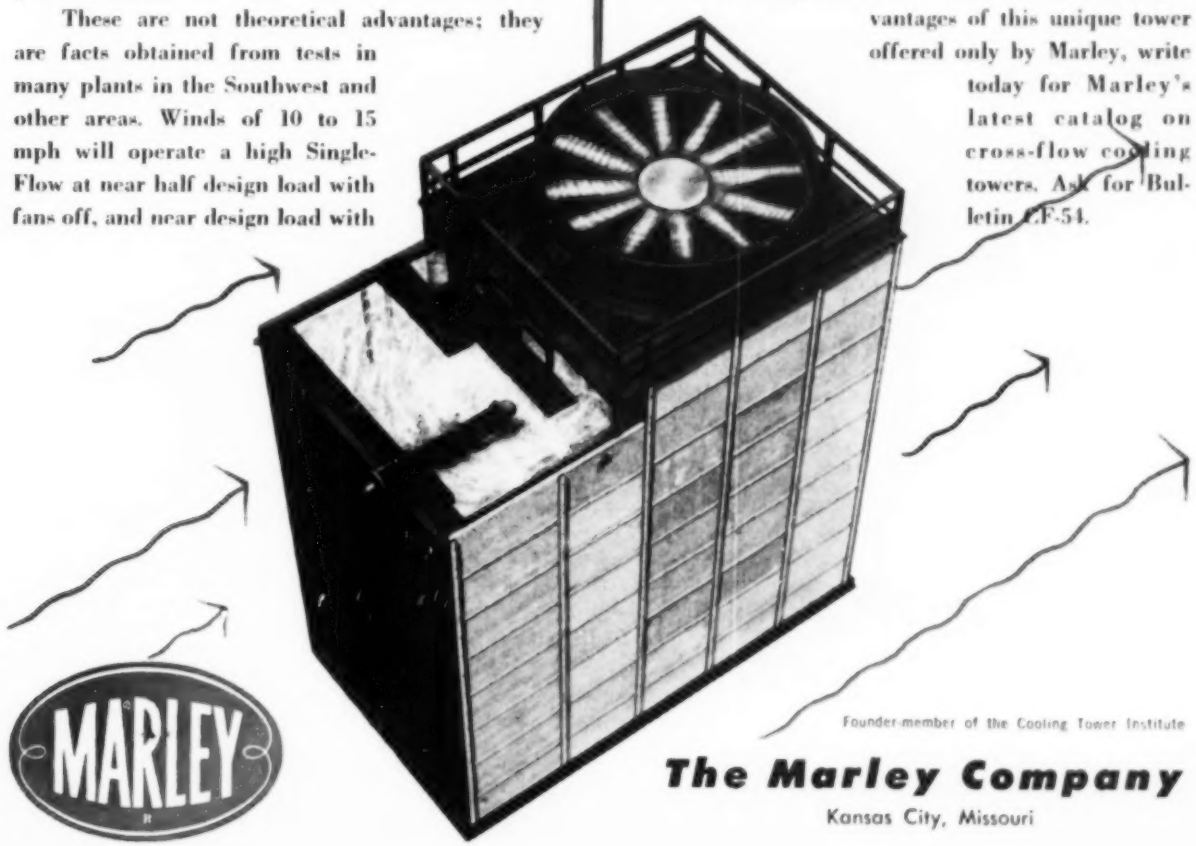
put the Weather Vane to work

Prevailing winds [illegible] my of one induced draft cooling towe[illegible] MARLEY SINGLE-FLOW. Instead, [illegible] wind is put to work by placing the one louvered face of the Single-Flow to utilize this source of natural cooling potential. Results: a high degree of atmospheric cooling that gives performance a substantial lift . . . a real power saving in day-to-day operation . . . a comfortable margin of safety in the event of power failure.

These are not theoretical advantages; they are facts obtained from tests in many plants in the Southwest and other areas. Winds of 10 to 15 mph will operate a high Single-Flow at near half design load with fans off, and near design load with fans at half speed. This means positive operating economy that every plant is seeking.

Another advantage of the Single-Flow is that with its one open side properly positioned, prevailing winds can not cause recirculation of warm, moist air. That is why Marley places no 7-mile-per-hour test restriction on the Single-Flow, but permits you to test your tower realistically under existing local conditions.

For complete information on the many advantages of this unique tower offered only by Marley, write today for Marley's latest catalog on cross-flow cooling towers. Ask for Bulletin CF-54.



MARLEY

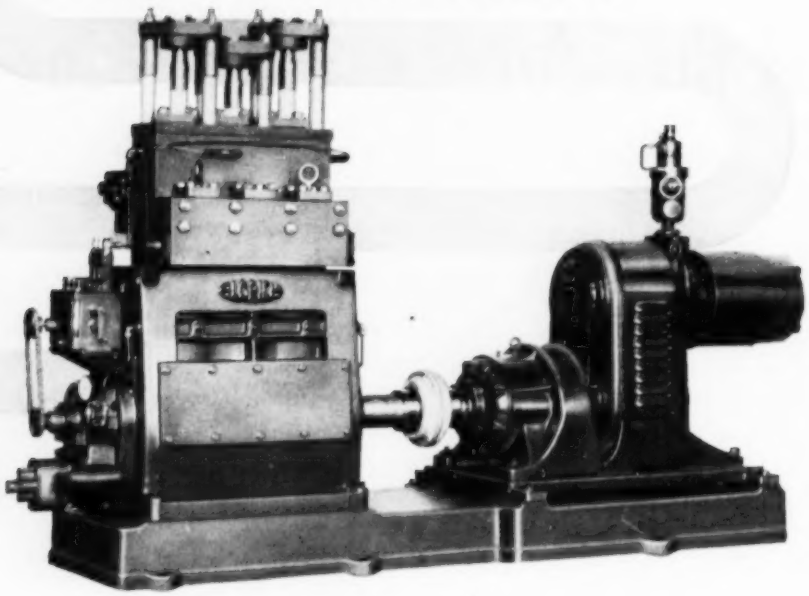
Founder-member of the Cooling Tower Institute

The Marley Company

Kansas City, Missouri

for your special pumping needs . . .

specify ALDRICH!



Here's an Aldrich Triplex specifically made to pump very highly abrasive slurry that would make short work of most pumps. A typical special Aldrich design, it features solid porcelain plungers—Kennametal ball valves and seats—an oversized oil pump for slow operation. Variable drive is provided by a U. S. Varidrive motor operated by Varitrol automatic control.

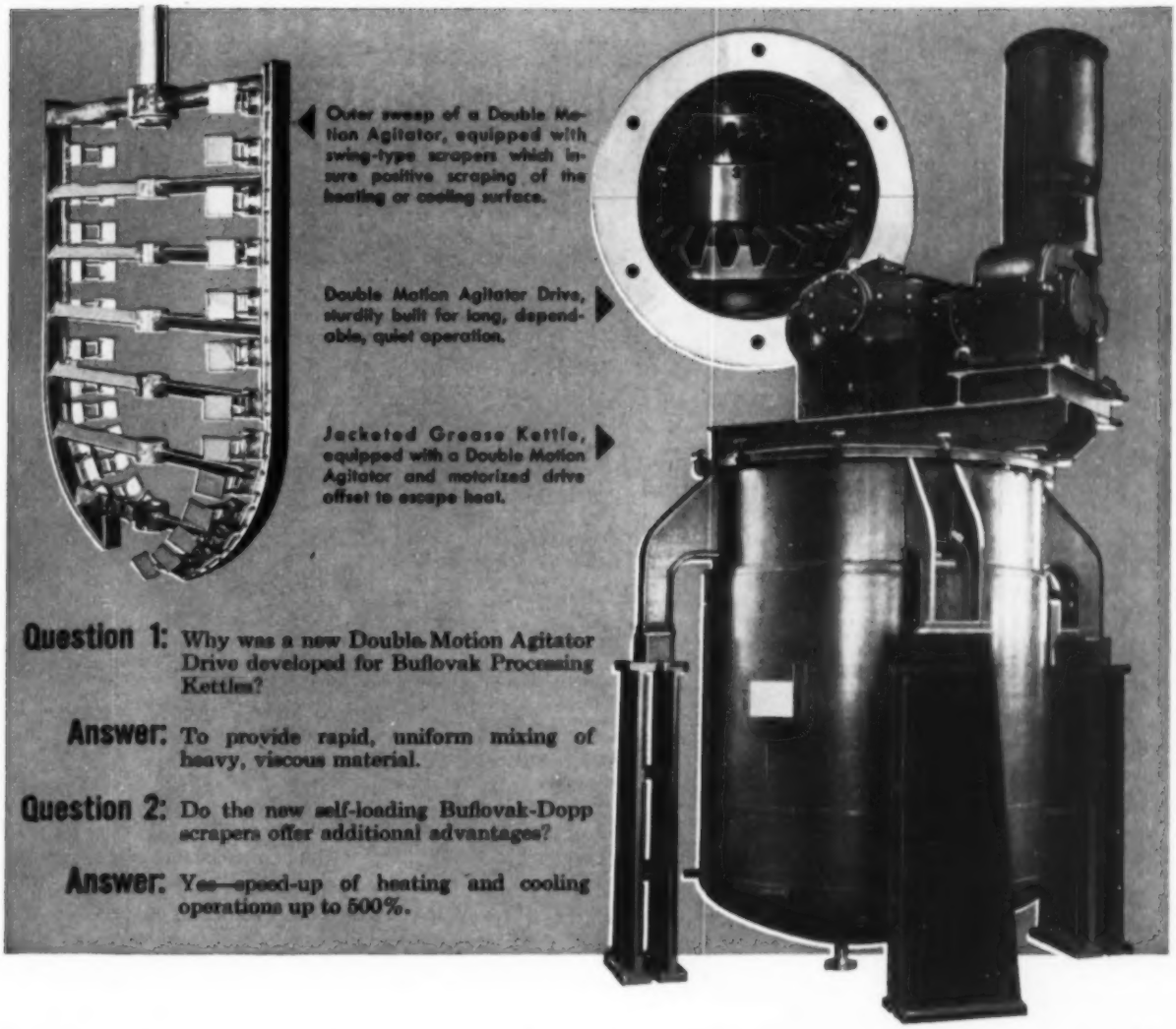
Aldrich Pumps are ideal for applications involving corrosion, high viscosity, high pressure, or abrasive materials . . . and the complete range of sizes insures a proper Aldrich pump for every need. Ask for recommendations to meet *your* chemical pumping needs.

the ALDRICH *pump company*

. . . Originators of the Direct Flow Pump

20 GORDON STREET • ALLENTOWN, PENNSYLVANIA

Representatives: Birmingham • Bolivar, N. Y. • Boston • Buffalo • Carmi, Illinois • Charleston, W. Va. • Chicago • Cincinnati • Cleveland • Dallas • Denver • Detroit • Duluth Houston • Los Angeles • New York • Oakland, Calif. • Philadelphia • Pittsburgh • Portland, Ore. • Richmond, Va. • Rochester • Salt Lake City • San Francisco • Seattle Somerville, Mass. • Spokane, Wash. • Syracuse • Tulsa • Washington, D. C. • Youngstown • Export: Petroleum Machinery Corp., 30 Rockefeller Plaza, New York 20, N. Y.


Outer sweep of a Double Motion Agitator, equipped with swing-type scrapers which insure positive scraping of the heating or cooling surface.
Double Motion Agitator Drive, sturdily built for long, dependable, quiet operation.
Jacketed Grease Kettle, equipped with a Double Motion Agitator and motorized drive offset to escape heat.

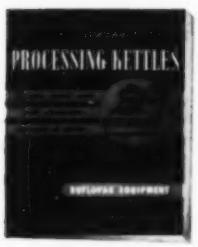
Question 1: Why was a new Double-Motion Agitator Drive developed for Buflovak Processing Kettles?

Answer: To provide rapid, uniform mixing of heavy, viscous material.

Question 2: Do the new self-loading Buflovak-Dopp scrapers offer additional advantages?

Answer: Yes—speed-up of heating and cooling operations up to 500%.

Have you questions about processing kettles that you would like answered?



For more complete information about Buflovak-Dopp Processing Kettles, write for Catalog 356-R.

Most everyone has some questions. And many of them have found the answers through pre-testing their products in our Pilot Plant . . . an important part of the *Buflovak* Research and Testing Laboratory.

You have the same opportunity to find the answers to your questions, as these facilities and an experienced engineering staff are maintained to help you.

To determine the right answers to better processing, many factors must be considered . . . such as the product, the design of the equipment, the type of agitation, and the handling of the finished material.

To improve your present processing methods or to find the most effective method for new and untried processes, the safest procedure is to process a quantity of the product and observe results.

This accurate data, when gathered and evaluated, will determine the precise equipment needed. Kettles can then be designed and built to most economically and profitably fulfill your expected requirements.

Let us know what questions you have and we'll help you find the answers.

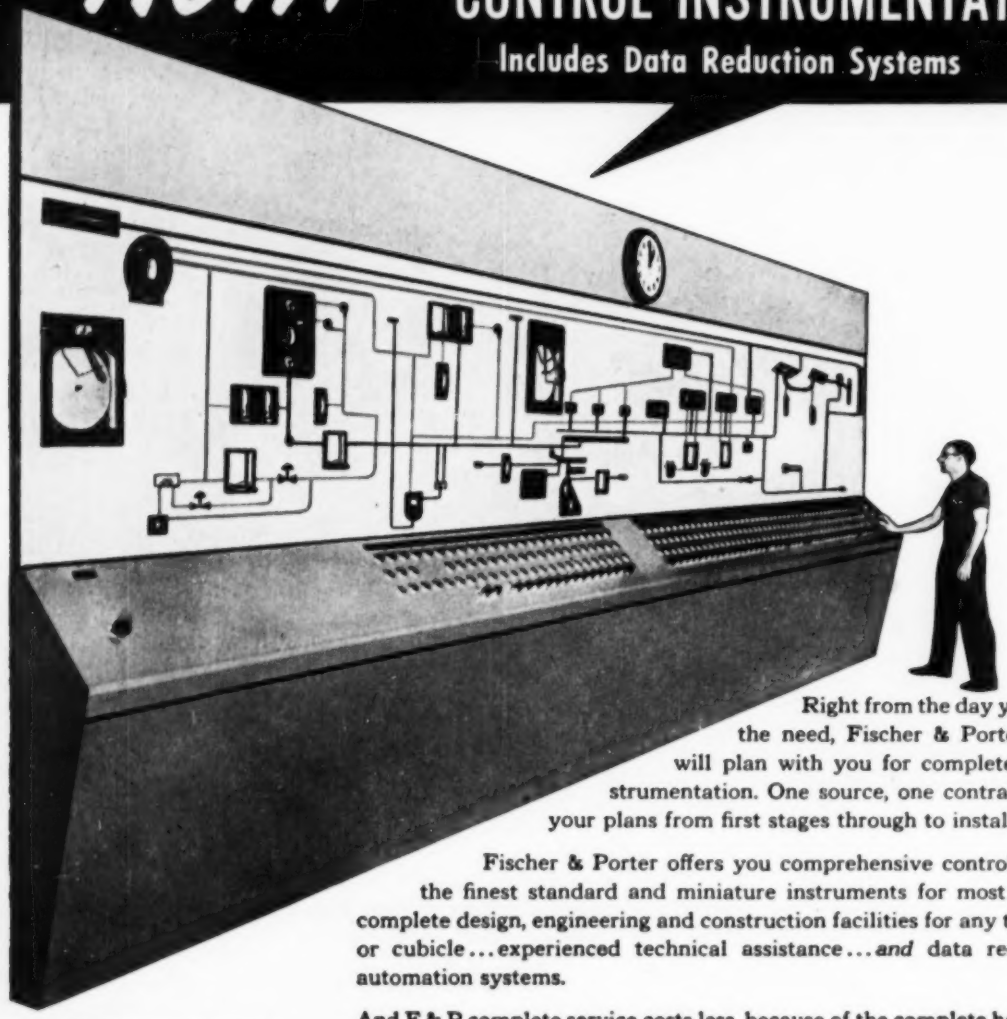
BUFLOVAK EQUIPMENT DIVISION
BLAW-KNOX COMPANY
1567 Fillmore Avenue, Buffalo 11, New York

BLAW-KNOX

BUFLOVAK PRODUCTS: evaporators • dryers (atmospheric and vacuum) • solvent recovery and distillation equipment • chemical plant equipment • food processing equipment • kettles • fabricated processing equipment • vulcanizers . . . plus a complete Pilot Plant for pre-testing processes and products.

NOW! FISCHER & PORTER'S COMPLETE CENTRALIZED CONTROL INSTRUMENTATION

Includes Data Reduction Systems

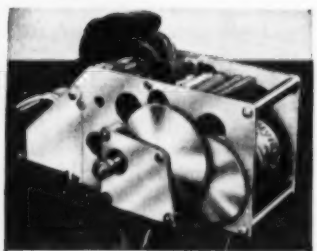


Right from the day you recognize the need, Fischer & Porter Company will plan with you for complete process instrumentation. One source, one contract—will take your plans from first stages through to installation.

Fischer & Porter offers you comprehensive control coverage—the finest standard and miniature instruments for most variables... complete design, engineering and construction facilities for any type of panel or cubicle... experienced technical assistance... *and* data reduction and automation systems.

And F & P complete service costs less, because of the complete handling from beginning to end in one plant.

Use all the advantages of automation. Write, call or wire today for complete information and engineering assistance.



F & P is first with a Data Reduction and Automation Division. Now available is a new digital converter, which provides completely automatic logging from sensing elements to coded or tabulated digital data output.

complete process instrumentation

FISCHER & PORTER CO.

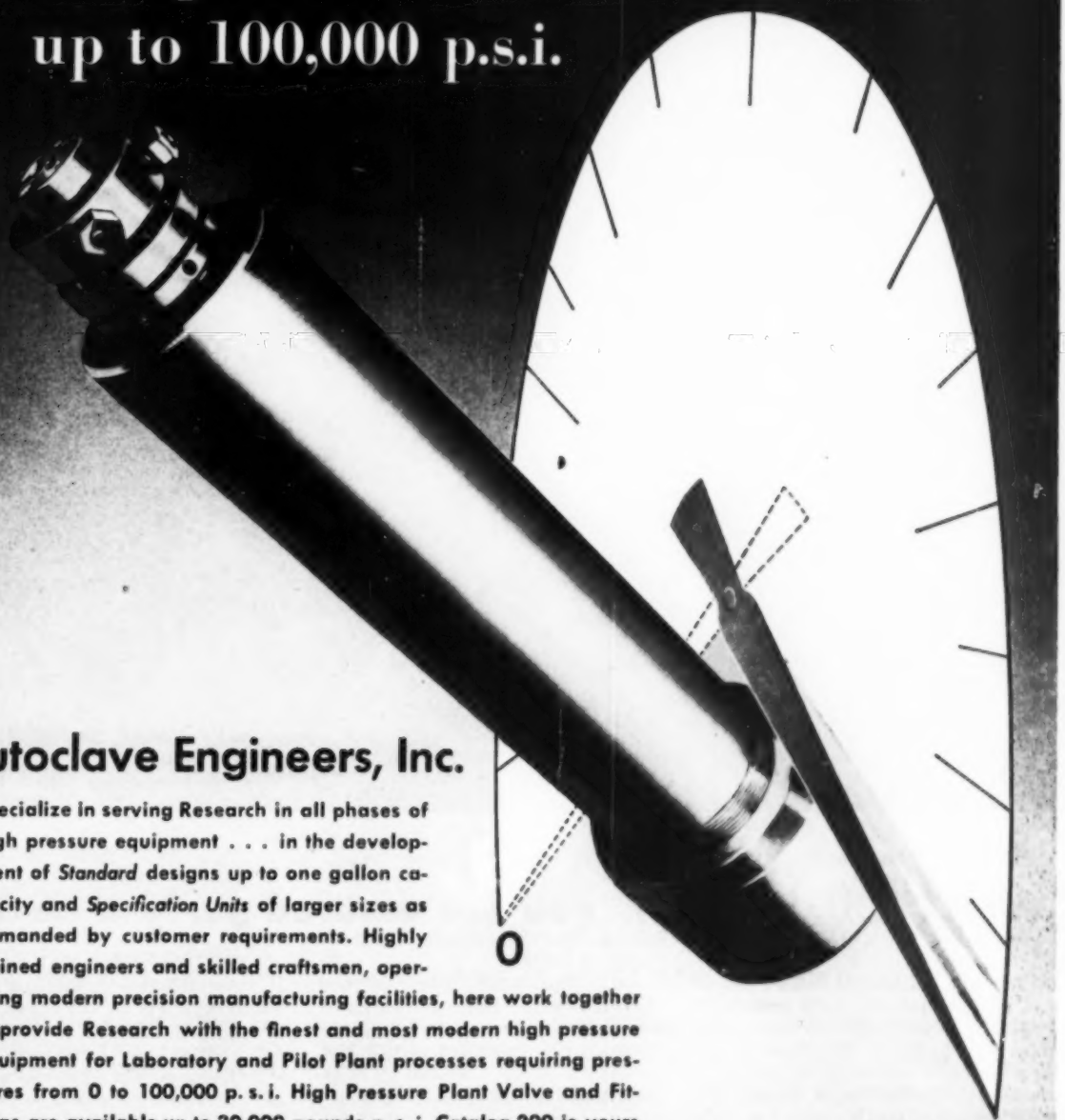
101 County Line Road, Hatboro, Penn.

FP

Measuring, Recording, and controlling instruments—Control Panels—Data Reduction Systems—Contract Instrumentation Research—Chlorination Equipment—Glass Specialties.

LA-1004

For Laboratory and Pilot Plant ...High Pressure AUTOCLAVES up to 100,000 p.s.i.



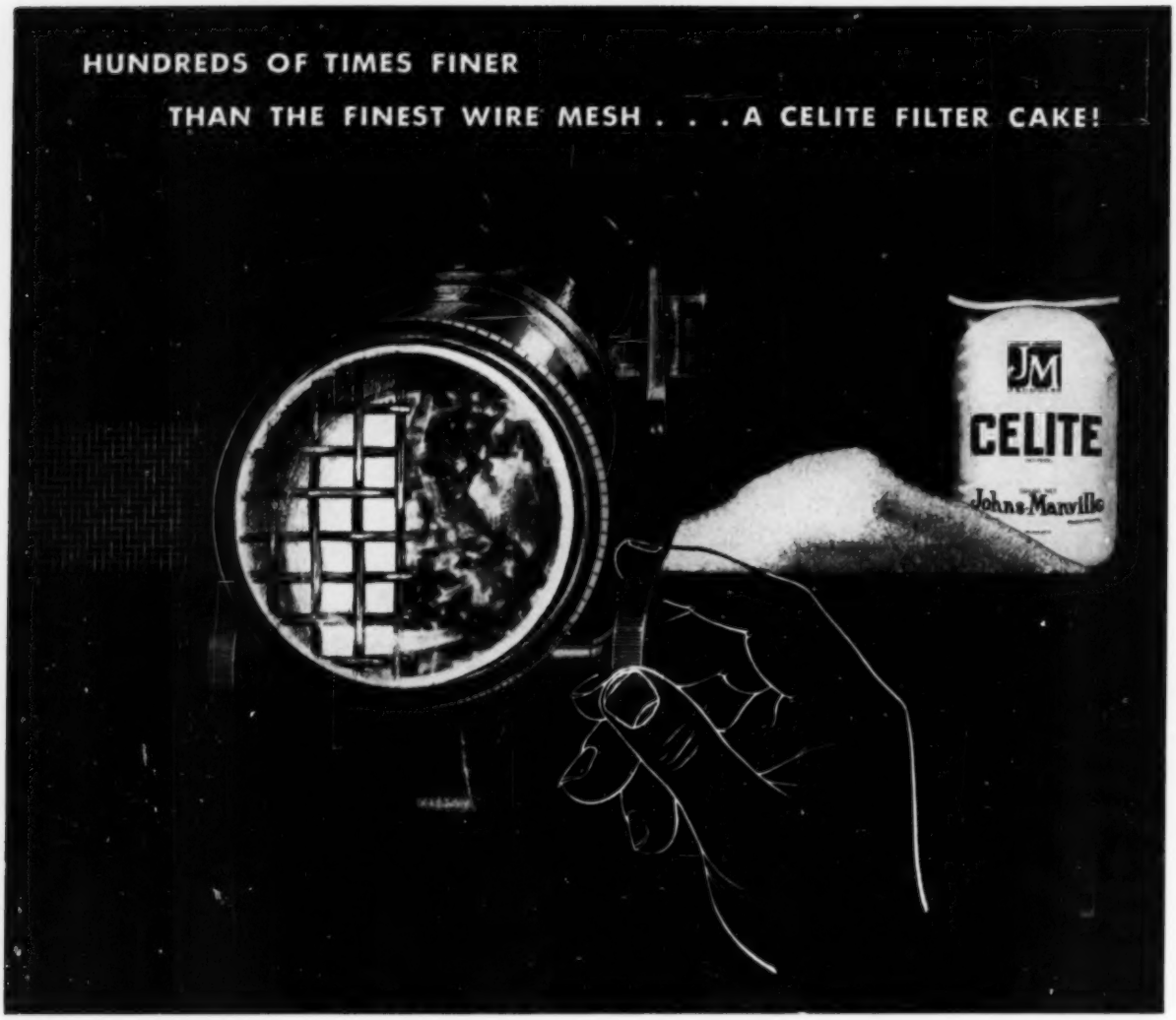
Autoclave Engineers, Inc.

specialize in serving Research in all phases of high pressure equipment . . . in the development of *Standard* designs up to one gallon capacity and *Specification Units* of larger sizes as demanded by customer requirements. Highly trained engineers and skilled craftsmen, operating modern precision manufacturing facilities, here work together to provide Research with the finest and most modern high pressure equipment for Laboratory and Pilot Plant processes requiring pressures from 0 to 100,000 p. s. i. High Pressure Plant Valve and Fittings are available up to 30,000 pounds p. s. i. Catalog 200 is yours for the asking.

SPECIALISTS IN LABORATORY AND PILOT PLANT HIGH PRESSURE EQUIPMENT

AUTOCLAVE ENGINEERS, INC.

860 EAST 19TH ST. • ERIE, PENNSYLVANIA



With Celite Filtration you are assured perfect clarity

HERE is a clarification method which can remove even the finest suspended solids . . . a Celite* Filter Cake contains more than 2,500,000 filter channels per square inch of surface. Here, too, is a method so flexible that it permits the right balance of fast flow rate and high capacity, with the degree of purity and clarity required.

Celite powders may be used with any type of conventional filter. Only 2 simple steps are required. First, a "pre-coat" of Celite is deposited on the filter medium. Second, small amounts of Celite are added to the solution, to form a continuously fresh filter surface. To meet different filtration requirements, Celite is available in nine standard grades of microscopically controlled particle size. Utmost uniformity is assured by exclusive processing techniques.

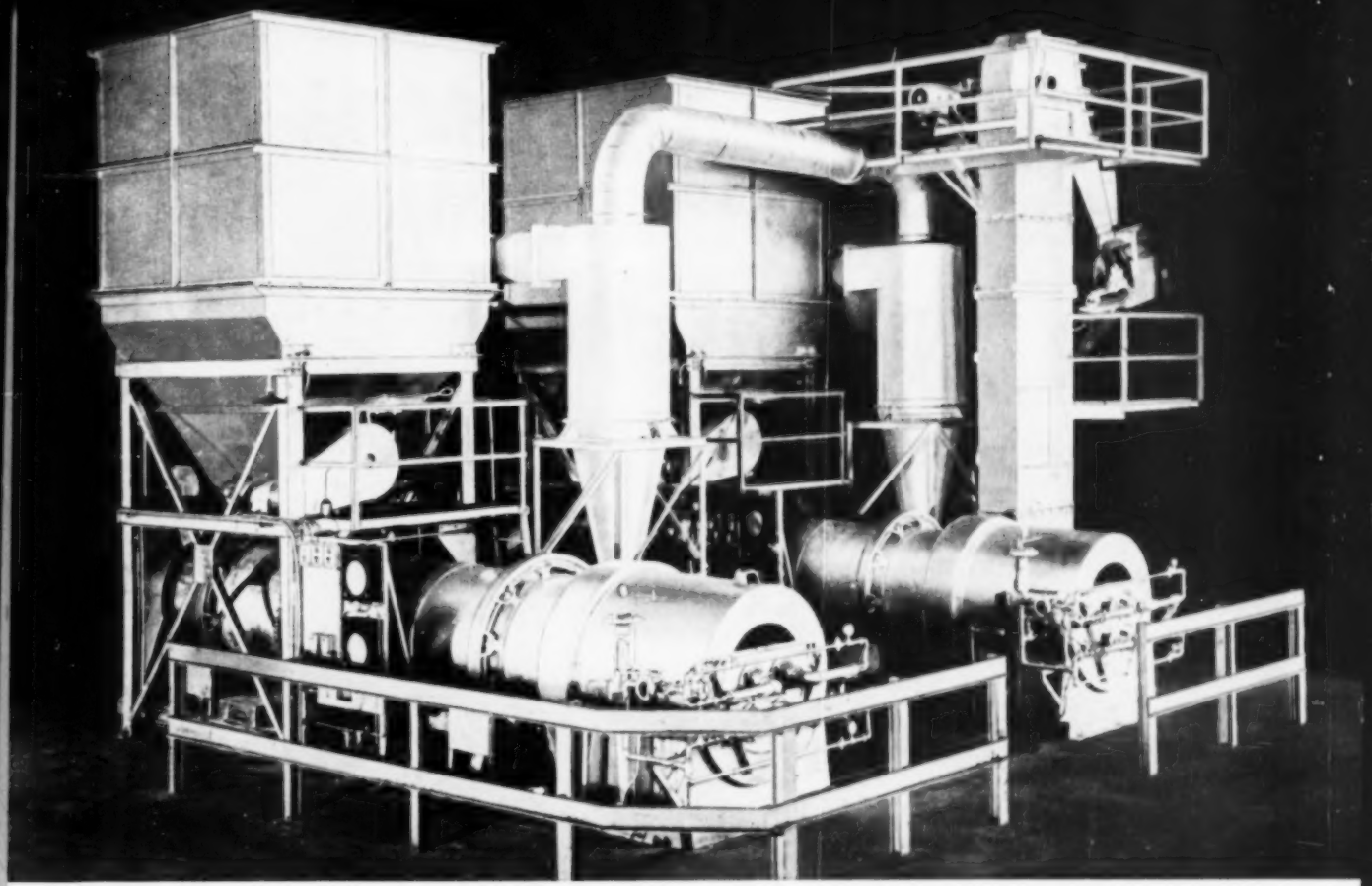
The extraordinary efficiency and flexibility of Celite Filtration have made it the standard for entire industries. For perfect clarity in food products such as jellies, sugar, wine, beer . . . for highest purity in antibiotics . . . for removal of impurities from chemicals, petroleum, dry cleaning solvents . . . Celite offers unequalled advantages.

If you want to improve your present filtration system or find an economical way to utilize filtration in your processing, investigate the Celite method now. One of the Johns-Manville Celite Filtration Engineers will gladly discuss your problem. These men are backed by complete technical services and the Johns-Manville Research Center, largest laboratory of its kind in the world. For further information write Johns-Manville, Box 60, New York 16, N. Y. In Canada, 199 Bay Street, Toronto 1, Ontario.

*Celite is Johns-Manville's registered Trade Mark for its diatomaceous silica products.

JOHNS-MANVILLE JM PRODUCTS

Johns-Manville CELITE FILTER AIDS



compact *Twin Dryer* installation

Calciner and Cooler for Continuous Processing at Temperatures from 900°F. to 2100°F.

Special Stainless Steel Batch Dryer for Drying Fine Catalyst without Dust Loss.

Two completely self contained duplicate systems can be operated either singly — or together — assuring efficient production regardless of wide fluctuations in plant requirements.

● These dryers maintain maximum fuel economy and discharge material of uniform dryness despite variations in the moisture content of the feed. Highly efficient, the installation is another example of Bartlett-Snow's skillful, detailed approach to every drying problem—your assurance that the equipment furnished will be exactly suited to your particular requirement. Let us work with *you* on *your* next job.

DESIGNERS ENGINEERS

BARTLETT-SNOW
CLEVELAND 5, OHIO

FABRICATORS ERECTORS

Dryers • Coolers • Calciners • Kilns

"Builders of Equipment for People You Know"

THE Chicago Bridge & Iron Company is pleased to announce that hereafter the well known line of

CONKEY EQUIPMENT

FILTERS — EVAPORATORS
CRYSTALLIZERS

will be fabricated in CB&I's plants.

A sales and engineering office, staffed by Conkey Equipment personnel will be maintained in the New York office of the Chicago Bridge & Iron Company.

The highly specialized experience of Conkey Engineers in designing efficient units for chemical and process plants—plus the extensive fabrication and erection facilities of the Chicago Bridge & Iron Company will provide chemical and process plants with a service that cannot be duplicated.

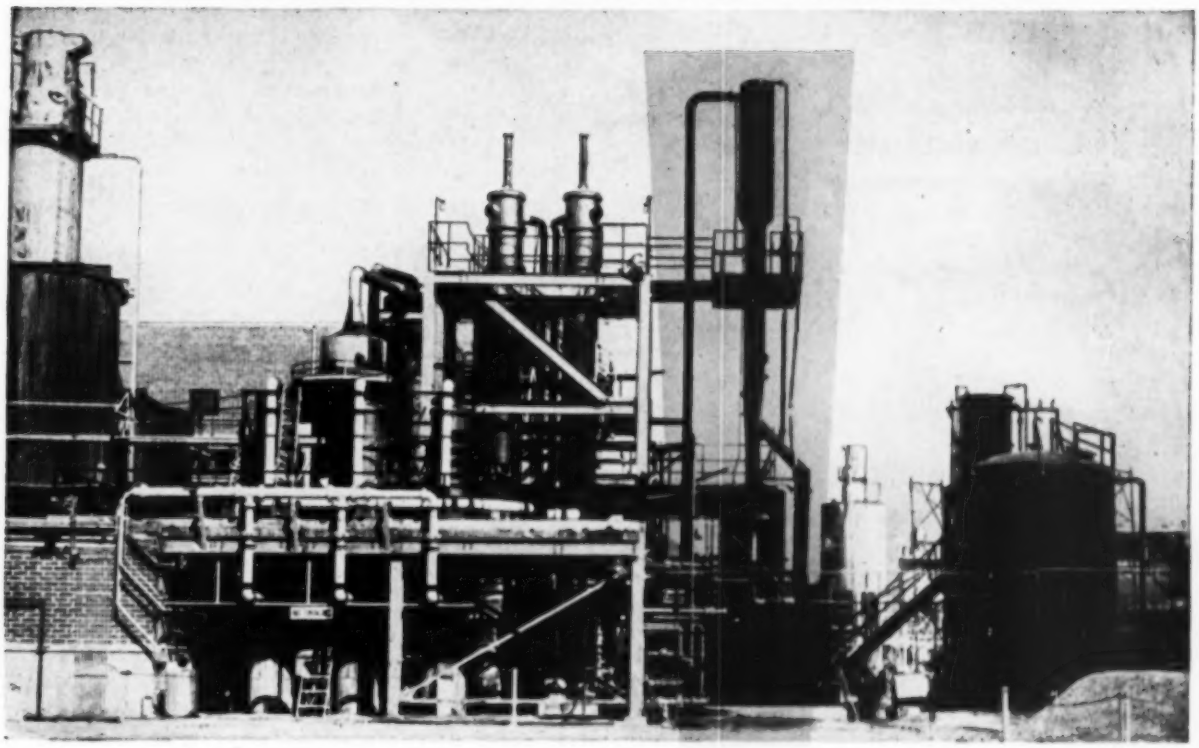
CHICAGO BRIDGE & IRON COMPANY

BIRMINGHAM, CHICAGO, SALT LAKE CITY and GREENVILLE, PA.

CONKEY EQUIPMENT

Atlanta 3 ..... 2131 Healey Bldg.	Los Angeles 17, 1541 Gen. Petroleum Bldg.
Birmingham 1 .... 1540 North Fiftieth St.	New York 6 ... 3322—165 Broadway Bldg.
Boston 10 ..... 1055—201 Devonshire St.	Philadelphia 3, 1640—1700 Walnut St. Bldg.
Chicago 4 ..... 2138 McCormick Bldg.	Pittsburgh 19 ..... 3207 Alcoa Bldg.
Cleveland 15 ..... 2232 Midland Bldg.	Salt Lake City 4, 560 West 17th South St.
Detroit 26 ..... 1546 Lafayette Bldg.	San Francisco 4 ..... 1536—200 Bush St.
Havana ..... 402 Abreu Bldg.	Seattle 1 ..... 1360 Henry Bldg.
Houston 2 ..... 2154 C & I Life Bldg.	Tulsa 3 .... 1643 Hunt Bldg.

RIEGEL-CAROLINA PLANT depends on I-R STEAM-JET REFRIGERATION



Chlorine dioxide plant of Riegel-Carolina Corp., showing reactors, absorber towers and I-R Steam Jet Refrigeration unit for chilled water at 50°F.

for safe, low cost production of ClO_2

CHLORINE DIOXIDE, long looked upon as a high-cost, 'super' bleach for wood pulp, is now being safely and economically manufactured at Riegel-Carolina Corp.'s Acme, N. C. mill at a rate of one and one-half tons a day.

The ClO_2 gas, generated in three reactors, is absorbed by water passing through two packed towers in parallel. The cooler the water, the more concentrated the solution, with resulting economy. 50°F. water for this purpose is provided by an I-R steam jet water vapor refrigerating unit, regardless of ambient temperature. And the only operating cost for refrigeration is the cost of the steam used in the unit's ejectors.

In addition to the I-R refrigerating unit, the bleach plant is served by I-R chemical pumps, of IRCAMET construction—entirely successful with the corrosive solutions.

This is another example of how Ingersoll-Rand job-engineered equipment serves the paper and chemical industries. I-R experience on thousands of specialized jobs like this is your best assurance of maximum efficiency and economy in meeting *your* exact requirements.

Ingersoll-Rand

11 Broadway, New York 4, N.Y.

45

PUMPS • COMPRESSORS • VACUUM EQUIPMENT • GAS & DIESEL ENGINES • TURBO-BLOWERS • AIR & ELECTRIC TOOLS

for *Low*
VACUUM PUMP MAINTENANCE COSTS and BETTER VACUUM . . .
it's the
HILCO OIL RECLAIMER
VACUUM for PUMP USERS . .

Oil Reclaimer
A simple, economical and efficient method of restoring contaminated lubricating and sealing oil to the full value of NEW OIL. The HILCO will produce and maintain oil free of solids, gums, water and gases in a continuous, all-electric, automatic operation.
Be SURE of clean oil in your HIGH VACUUM PUMPS
HILCO
OIL RECLAIMER SYSTEMS . .
• WRITE FOR COMPLETE DETAILS IN THE FREE BULLETIN
Recommendations at no Obligations
[redacted]
144 W. Fourth St., Elmira, N. Y. •
[redacted]
IN CANADA — UPTON-BRADEEN-JAMES, Ltd.
890 Yonge St., 3464 Park Ave., Montreal

MARGINAL NOTES

A "Spotty" Collection

Case Studies in Commercial Chemical Development. John E. Ullmann. Chemonomics, Inc., New York (1953), 134 pp. $5.00.

Reviewed by H. K. Nason, Director of Research, Monsanto Chemical Co., St. Louis 1, Mo.

This multilith-printed and magazine-stapled booklet in paper covers with tape-back reinforcement comprises two sections, one devoted to consumer products, and the other to industrial products. A short introduction, a bibliography, and an index of companies mentioned are included.

The consumer section discusses the development and marketing of sixteen such diverse items as antibiotics and Kleenex, isonicotinic hydrazide and Coca Cola, shellac and Tabu perfume, drug wholesaling and frozen orange juice. The industrial section ranges over twenty-one topics from the sulfur industry to boiler compound, from plastics (general) to Calgon, from hydraulic fluids to pholoroglucinol, and from petroleum chemicals to ethylhexanediol.

The term "case study" usually implies an analytical investigation of a project or situation, in the course of which all important factors bearing on the matter are isolated and described, and the time sequence of events is established. The cause-effect relationships may be detailed or may be left to the student's deductive abilities, but the essential data must in any event be supplied. A collection of such case studies for commercial developments in the chemical and allied industries could be a useful contribution.

Unfortunately, the present offering is not such a contribution. The individual topics appear to have been assembled, not by first-hand study of the basic facts and factors involved. The result might yet have been useful had the sources selected been authoritative and comprehensive, and had critical judgment been exercised in selecting, analyzing, and editing. The result is a spotty collection, with the quality of each chapter dependent almost directly upon the quality of the original source. Some are good, some are indifferent, and some are almost unbelievably bad.

A borrowed copy may be worth a casual perusal. Its purchase at the listed price cannot be recommended.

(More Marginal Notes on page 27)

(Advertisement)

Liquid Carry-Over Economically Controlled by Separators Made of Knitted Wire Mesh

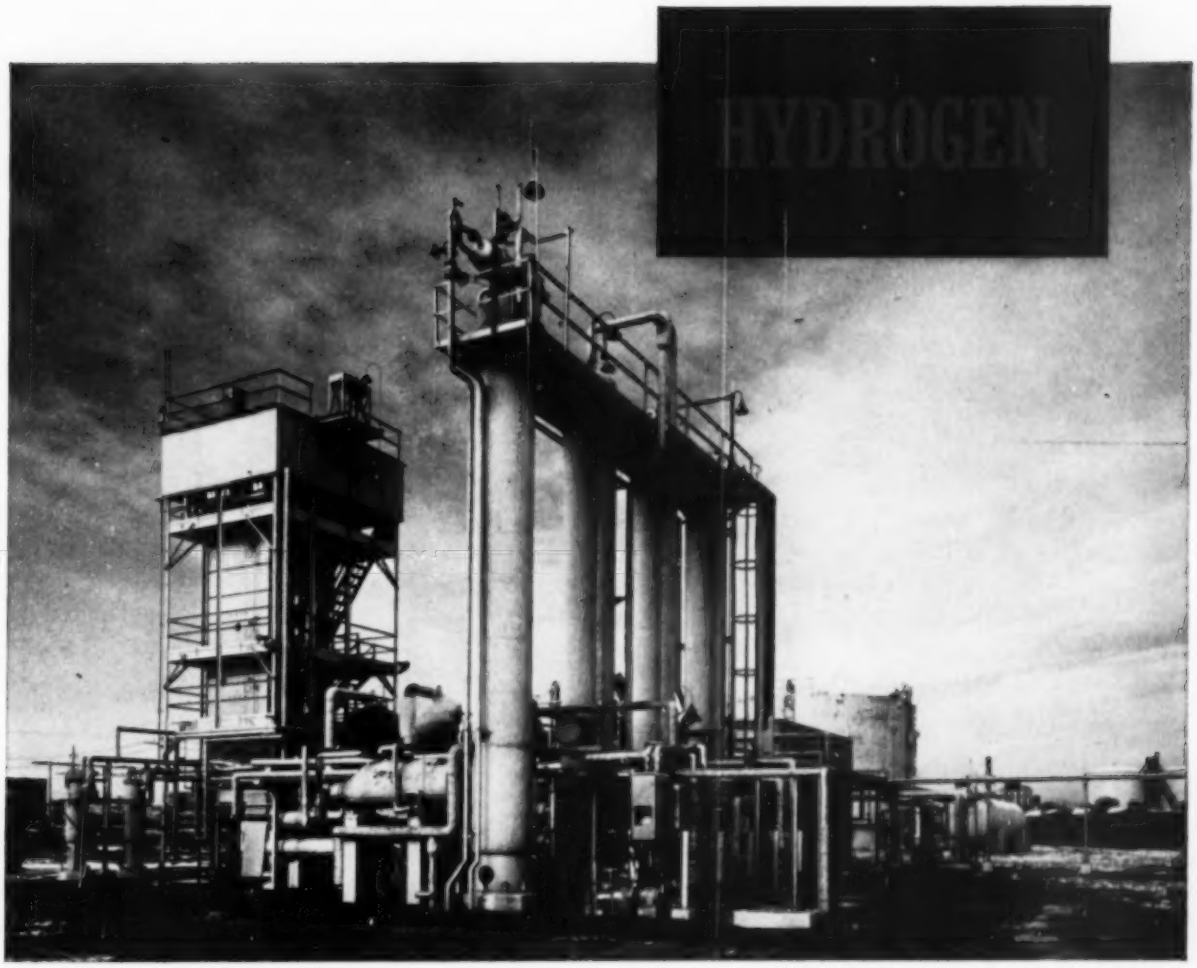
When the removal of unwanted – and often contaminating – liquid particles entrained in a gas is considered as basically similar to the filtering of solid particles from the same type of carrier, the simplicity and effectiveness of knitted wire mesh entrainment separators is more readily understood.

Small section of a Metex Mist Eliminator opened to show construction.

Known as Metex Mist Eliminators, these separators are built up from layers of knitted wire mesh into a unit, foraminous in structure, which removes the liquid particles by impingement and accumulation in depth. Though operating on the same principle as air filters of this type, they have one distinct advantage. The filtrant being liquid will drain from the Mist Eliminator by gravity. Entrainment removal can therefore be considered as a "continuous" rather than a "batch" operation since the "filter" does not have to be cleaned.

Metex Mist Eliminators were first used about 10 years ago to remove the liquid entrainment in a fractionator tower in one of our leading petroleum refineries. The efficiency of, and the operating economies effected by, this first installation have since been repeated in unnumbered operations which include not only petroleum refining, but petrochemical and chemical processing operations in this country and abroad.

Mist Eliminators can be easily installed in new or existing vessels. They have no moving parts to require power or servicing and need no special housings. Experience shows that they will operate over an unusually wide range of velocities with a pressure drop generally less than 1" of water. Entrainment removal efficiencies of 99% and better are commonly reported. For full information write Entrainment Separator Department, Metal Textile Corporation, Roselle, New Jersey.



At new Chicago plant of The Southern Cotton Oil Company

Hygirtol plant produces high purity hydrogen continuously

THIS GIRDLER HYGIRTOL* PLANT provides a continuous supply of hydrogen of a purity exceeding 99.8%. Operation of the plant is practically automatic, clean, safe, instrument-controlled, and its output can be varied readily from 50% to 110% of rated capacity.

Girdler designs and builds complete process plants such as this, assuming responsibility for all phases of planning and construction. This assures coordination and sound results. For complete information, call the nearest Girdler office.

*HYGIRTOL—Trade Mark of The Girdler Company

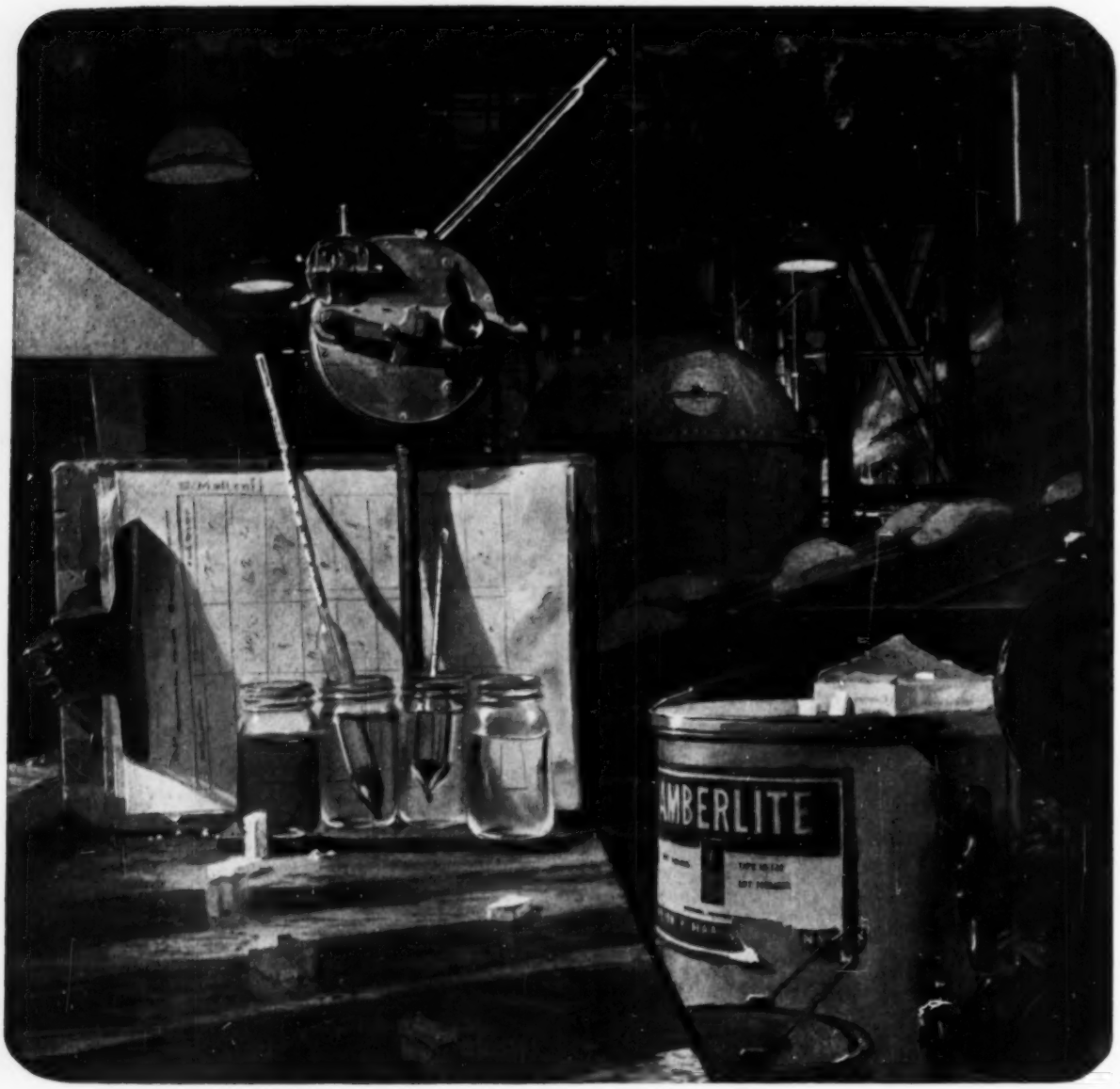
GIRDLER DESIGNS processes and plants
GIRDLER BUILDS processing plants
GIRDLER MANUFACTURES processing apparatus

GAS PROCESSES DIVISION:

Chemical Processing Plants
Hydrogen Production Plants
Hydrogen Cyanide Plants
Synthesis Gas Plants
Carbon Dioxide Plants
Gas Purification Plants
Plastics Materials Plants
Sulphur Plants
Acetylene Plants
Ammonia Plants
Ammonium Nitrate Plants
Hydrogen Chloride Plants
Catalysts and Activated Carbon

The **GIRDLER** Company
A DIVISION OF NATIONAL CYLINDER GAS COMPANY
LOUISVILLE 1, KENTUCKY

GAS PROCESSES DIVISION: New York, Tulsa, San Francisco
In Canada: Girdler Corporation of Canada Limited, Toronto



Sugar by the ton: 99.99% pure

There aren't many chemicals—let alone foodstuffs—as chemically pure as sugar prepared from sirups treated with Amberlite® ion exchange resins. These resins remove ash from cane sirup solutions, cut down sugar loss in molasses, yield sugar of the highest quality.

Other products, too, benefit from proper treatment with the Amberlite ion exchangers. Soft curd milk for infants may be produced from cow's milk, for example. Stabilized cream and condensed milk, readily soluble in hot drinks, may be prepared. Crude glycerin can be converted to C.P. grade by an ion exhange process.

The list is long. Gelatin, amino acids, fruit drinks, bland sirups from fruit wastes, vitamins, dextrose sirups, and others may be purified at low cost by means of Amberlite ion exchange.

Why not write us about your problem . . . ask us about Amberlite ion exchange resins? Take this opportunity to find out why, in ion exchange, the *right* way is the *Amberlite* way.

Ask for "Amberlite Ion Exchange," 16 pages of technical information on the applications for ion exchange in industry.

ROHM & HAAS COMPANY

THE RESINOUS PRODUCTS DIVISION, PHILADELPHIA 5, PENNSYLVANIA

MARGINAL NOTES

(Continued from page 24)

Provides Basic Background

Betz Handbook of Industrial Water Conditioning, 4th ed. W. H. & L. D. Betz, Editor & Publisher, Philadelphia 24 (1953), 248 pp. $3.00.

Reviewed by Frank U. Neat, Senior Engineer, Consolidated Gas Electric Light and Power Company of Baltimore, Baltimore 3, Md.

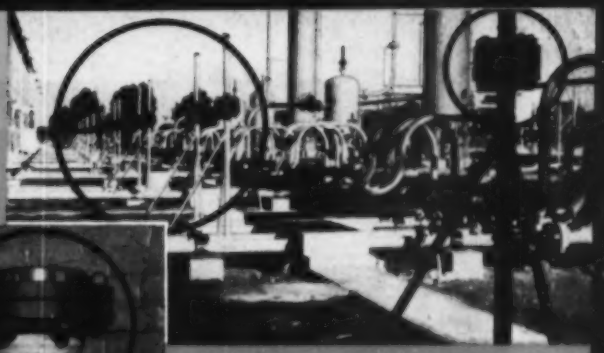
Water engineers and chemists will not be too happy with the opening statement of this work that pure water would eliminate the need for their specialty. Such a statement implies that if the water coming into the plant could be made pure—and this is not beyond the realm of possibility—all of our troubles with scale, corrosion, staining and such would be cured. We now find too many nonchemical people, and some chemical, who believe or would believe so and the next edition of this work should clarify this statement. There are too many of us now trying to keep pure water pure and modifying pure water so as to prevent it from dissolving or otherwise harming our equipment and piping to leave the interpretation of this statement to the discovery of another phrase that water is the universal solvent.

But he who is interested in industrial water, or potable water for that matter, should welcome this revised and expanded edition. Those who own previous editions will find a new treatment of subjects contained in those editions and added material of more up-to-date nature. Those who do not own previous editions should be cautioned that, because of the amiable disagreement among water engineers and chemists, the work carries a slight bias towards the methods of the authors. This bias is not detrimental to the worth of the volume as the authors' methods have no more shortenings than other methods for the same purpose.

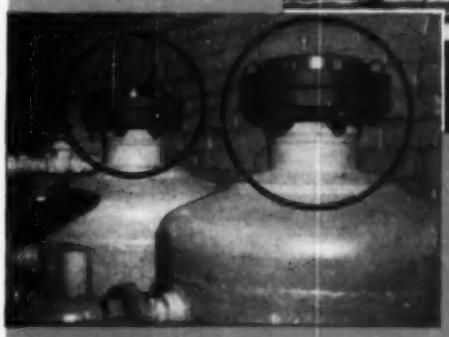
The first part of this book, 39 chapters and 192 pages, is devoted to the unit operations of water purification, control and use. Too much stress may have been put on this work to connect it with the particular problems of power generation, but the reader should not find it too difficult to apply the information to the particular operation or process of his primary concern. Limitations of each process or operation are plainly stated.

The second part of this work is devoted to analytical methods and apparatus. Here, again, the stress is on power generation. The first chapter of this

(Continued on page 29)

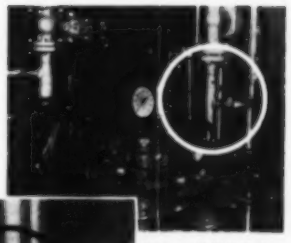


BS&B Safety Heads protect compressor lines at a South Texas condensate recovery—pressure maintenance plant.



Equipment and personnel within a plant are protected from the hazards of overpressure in these vessels by BS&B Safety Heads.

BS&B Safety Heads
Have Hundreds of Applications!



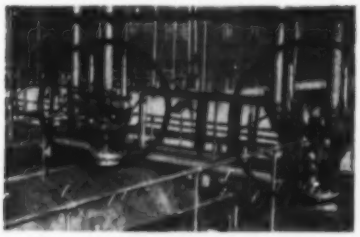
Here a BS&B Union Type Safety Head, with Monel rupture disc, is installed on a two-stage hydrogen compressor.

This BS&B Safety Head is mounted on the flare from a Pop Valve on an incoming gas line.

The variety of possible uses for BS&B Safety Heads is limited only by the number of different ways in which compressed air, gas or liquids—either bland or corrosive—are handled, processed or stored by our many manufacturing and processing industries! Wherever protection of a closed pressure system is required, there is a correct size and type of BS&B Safety Head to do the job! For detailed information, ask your BS&B Representative . . . or write to us direct.

BS&B Safety Heads

THE "CIRCUIT-BREAKER" OF
Any Pressured System

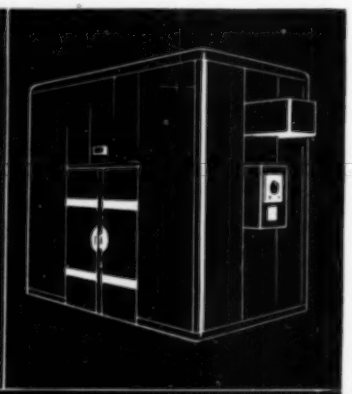


BS&B Combination Safety Head—Relief Valves protect 15,000 gallon butadiene storage tanks at an Akron, Ohio, rubber plant.

BLACK
SIVALLS &
BRYSON, INC.
Safety Head Division, Dept 2-DX7
7500 East 12th St., Kansas City 26, Mo.

EFFICIENCY
OVER 40 YEARS
BS&B
RELIABILITY

"NATIONAL" PROVIDES THE *Economical Solution* TO *Any Drying Problem!*



No matter what your product may be, it can be dried or otherwise processed at a lower cost per pound or other unit, in one or more of the various types of "NATIONAL" equipment.

High-speed production; maximum effective use of the drying medium under finely adjusted control; adaptability to existing plant conditions and future expansion; and the assurance of long, trouble-free operation are among the important reasons why "NATIONAL" machines are being erected in more and more chemical plants throughout the United States and in other countries.

NEW "P-4" CONSTRUCTION:

The result of a radically new approach to simplified Dryer construction. "P-4" Construction provides a precision-built, prefabricated structure, with trussed-and-tensioned insulated panels. It assures a more rigid, durable machine, with installation time in your plant reduced as much as 50%.

"ADD-A-UNIT" DESIGN

This unique accomplishment of "NATIONAL" engineering provides alternatives which are both practical and economical—(1) simplification of the initial installation based on present requirements; (2) maximum adaptability to step-by-step future expansion.

OTHER SPECIAL FEATURES

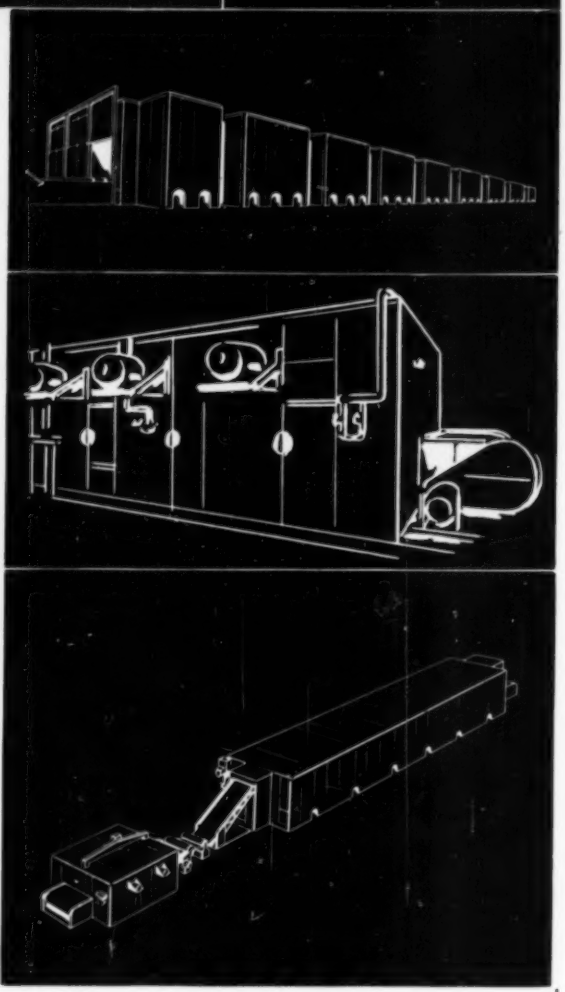
Patented Super-Power Fans, made in our own shops to specifications developed through years of industrial drying experience.

Patented Indexing Orifices, Turning Vanes and other devices and arrangements assure unequalled versatility and precision in air distribution and control.

The heat source may be steam, gas, oil or other medium. "NATIONAL'S" special gas firing systems, *Factory Mutual approved*, provide controlled uniformity of high temperatures; absolute safety; and lower maintenance costs.

• • •

When you have a *new* product which presents a drying problem, or if you want to improve your present drying processes, call "NATIONAL" Engineers for consultation. It is your surest way to improved production and lower over-all costs.



Illustrated above are typical "NATIONAL" Dryers for the Chemical Industry. From top to bottom: Cross-circulation type Truck Dryer; large multiple-unit Tunnel Dryer; single-apron Conveyor Dryer; large multiple-unit Tunnel Conveyor Dryer.

THE NATIONAL DRYING MACHINERY CO.
LEHIGH AVENUE and HANCOCK STREET
PHILADELPHIA 33, PENNA.

MARGINAL NOTES

(Continued from page 27)

section is general in nature and explains the choice of methods.

This section of the work is illustrated with apparatus peculiar to the authors' activities. This is not detrimental in that the apparatus appears to be conveniently arranged and sized and is packed so that a convenient field laboratory, except for sampling, may be rapidly set up.

This volume can be recommended for a spot in the library of the laboratory and of those who should have a basic idea of industrial water-treatment processes. As the authors state, it will provide a basic background for the engineer or chemist working with industrial water but is not intended to provide complete or specific knowledge of all industrial water problems. The analytical section may well prove of value in the transition of the analytical chemist to the chemistry of industrial water.

Vapor Pressure of Organic Compounds, T. Earl Jordan. Interscience Publishers, Inc., New York (1954), 266 pp. $14.50.

The compounds treated in this book are divided into ten chapters—hydrocarbons; halogen compounds; alcohols, aldehydes, ethers, ketones and oxides; acids, acid chlorides, and anhydrides; esters; nitrogen compounds; phenols; organic compounds containing arsenic, selenium, sulfur, and silicon; organic compounds containing antimony, boron, gallium, lead, phosphorus, tin, thallium, beryllium, and zinc. Each chapter is divided into four parts: a master table, a series of individual tables, references, and a series of plates. The index locates the compounds in the master table of each chapter.

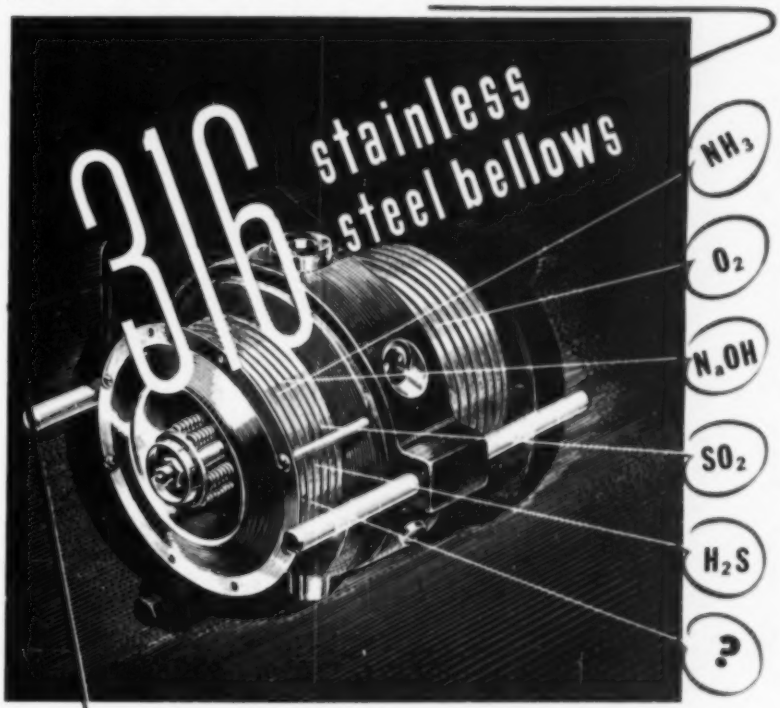
This summary of vapor pressure data was gathered primarily for the benefit of the industrial worker, but the author hopes that this work will be helpful also to the chemist and chemical engineer who may have occasion to use vapor-pressure data.

Books Received

Magnetic Cooling. Harvard Monographs in Applied Science No. 4. C. G. B. Garrett. Harvard University Press, Cambridge, Mass., and John Wiley & Sons, Inc., New York (1954), 110 pp. $4.50.

The Microscopy of Metals (Lectures delivered at the Institution's Refresher Course 1953). The Institution of Metallurgists, London, S.W. 1, England. 132 pp. 15/6d.

your extra measure of **PROTECTION!**

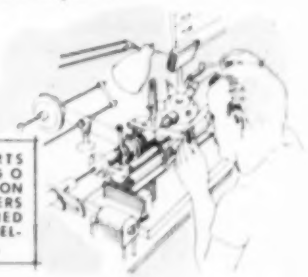


for the difficult fields of CHEMISTRY

BARTON FLOWMETERS supply that extra measure of protection with 316 stainless steel bellows. Their corrosion resistance and rupture-proof features form a durable quality that gives long life under unusually tough conditions without affecting such measurement features as high accuracy and sensitivity. **BARTON FLOWMETERS** firmly established in many industries have stood the test of time and conclusively prove that **YOU CAN DEPEND ON BARTON** for long term economy!

Experienced sales engineers representing BARTON, are located in most principal cities. The Barton line is fully described in literature available upon request.

MODEL 211 INDICATING SWITCH ACTUATES: *Audible or Visual Alarm*
INDICATES: *Flow Liquid Level Pressure Differentials*



BARTON INSTRUMENT CORPORATION
INDUSTRIAL INSTRUMENTS
1429 SOUTH EASTERN AVENUE LOS ANGELES 22, CALIFORNIA

Picture of A CONTINUOUS WAY TO PROCESS HOT* CHEMICALS

* Materials With Temperature Up to 1900° F. Are Being Sucessfully Handled. Tests Indicate Possibility Of Handling Even Hotter Materials

Here's a way to engineer efficient, continuous-cooling or conveying into your hot material processing.

Sandvik's steel-belt continuous coolers carry the material on a solid, endless, steel band of flat, stainless or carbon steel. This band "floats" on a patented water-bed arrangement which cools from beneath . . . no water gets on top of the band.

You can cool and convey, regulate thickness and graduate temperature while cooling, obtain desired sizes in the same operation, cool and strip off gelatinous materials in sheet form, cool loose and pulverized materials, cool solids in sheet form or crystallize liquids.

A steel belt provides a smooth, hard, impervious surface that is easy to keep clean. It has a high load capacity and a long service life. It can be fitted with simple discharge devices that scrape material off at any point. It can be of any length or width.

Sandvik steel belt units *without* the patented water-bed cooling arrangement can be used for other chemical processing functions such as drying, evaporating, conveying, carrying material through ovens, etc.

ENGINEERING SERVICE—Sandvik's engineering department will be glad to work with you in designing a conveyor to fit your operation. Sandvik has had over thirty years of experience in designing units to operate either as independent units or as integral parts of special processing equipment.

Write, wire or phone for further information.

SANDVIK STEEL BELT CONVEYORS • DIVISION OF SANDVIK STEEL, INC.
111 Eighth Ave., New York 11, N. Y. WAtkins 9-7180
Branch Office: 230 N. Michigan Avenue, Chicago 1, Ill. FRanklin 2-5638
IN CANADA: SANDVIK CANADIAN LTD., 5675 Royalmount Ave., Montreal 16, P. Q.

SS-89

SANDVIK STEEL BELT CONVEYORS

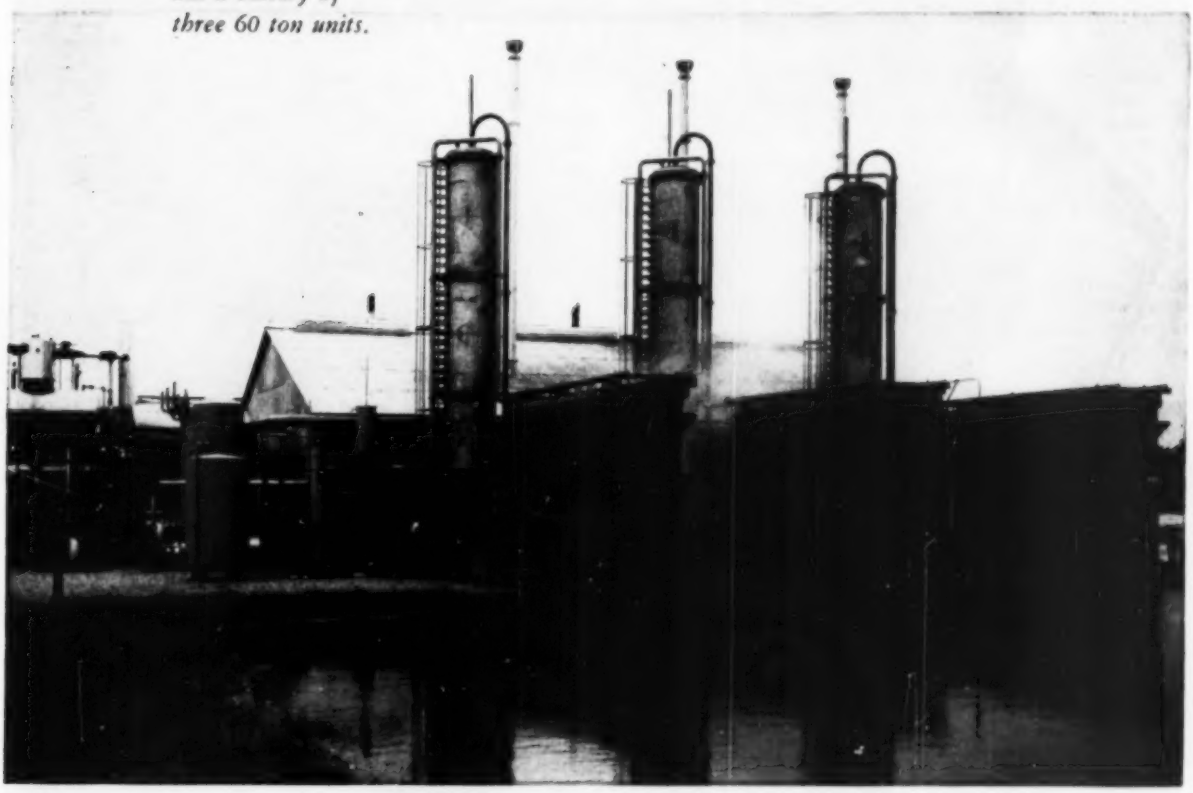
PILOT SCALE UNITS AVAILABLE FOR TEST PURPOSES

Experimental units are available to help you determine cooling rates and other data for your specific material.

Water-bed Section Test Tank

Complete Experimental Water-Bed Belt Cooler

Built for Commercial Solvents Corporation, this C & I Ammonia Oxidation Plant has a battery of three 60 ton units.



What's new in nitric acid?

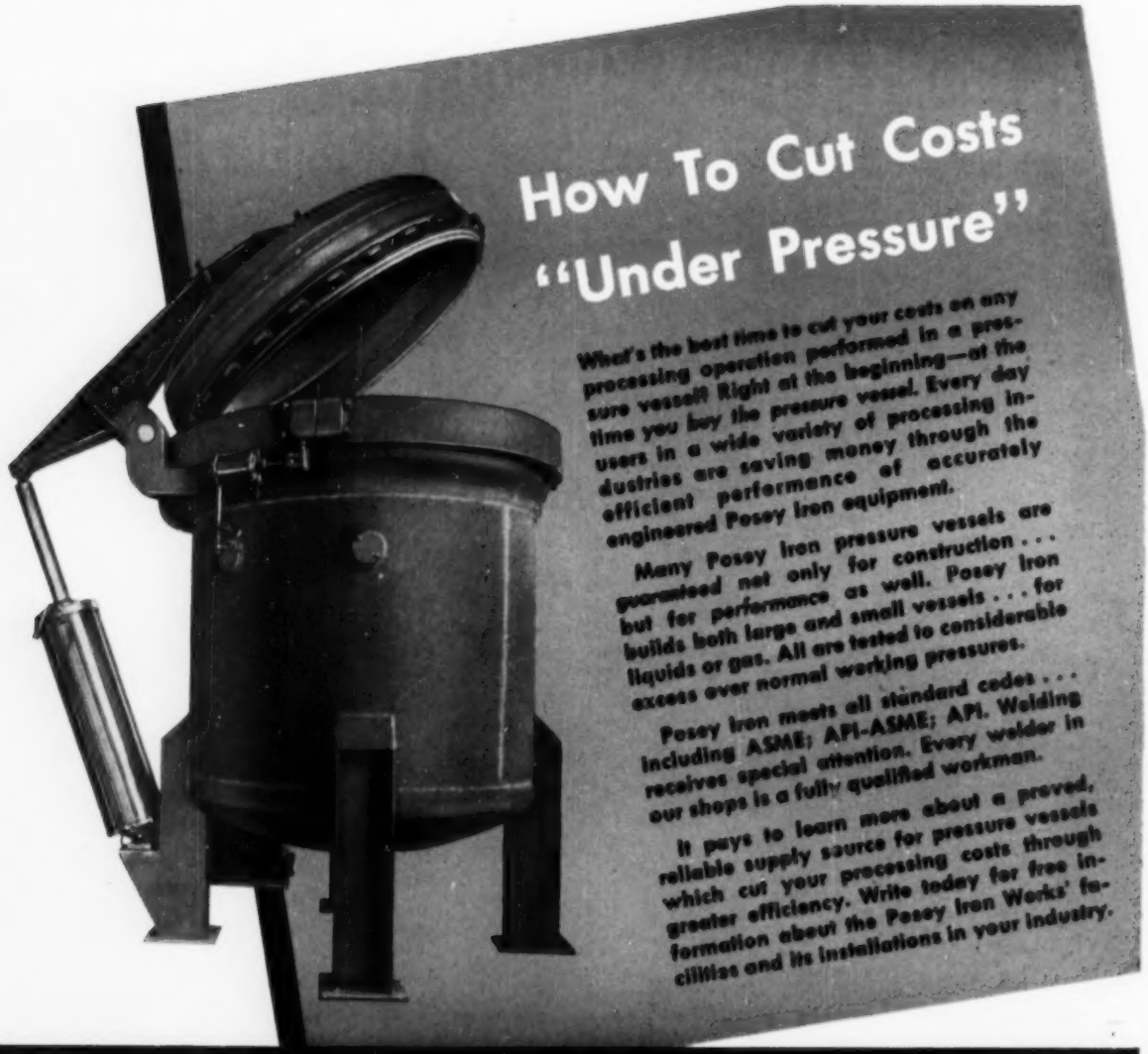
Here's one of the latest additions to an already impressive string of nitric acid plants designed and constructed by C & I. It's Commercial Solvents' new 180-ton-per-day installation at Sterlington, La. Nitric acid will be used to make solid ammonium nitrate by C.S.C.'s single step Stengel process.

In recent years, 90% of America's nitric acid plants have been designed, engineered and erected by C & I. Due to vast experience in this field, C & I is able to deliver these plants at a fixed cost on a fixed date with performance and production guaranteed. C & I is also prepared to furnish the newest type Ammonium Nitrate Solutions and Solids Plants and Complex Fertilizer Plants on this same basis.

Specialists in [C&I] *Processing Ammonia*

THE CHEMICAL & INDUSTRIAL CORP.

CINCINNATI 26, OHIO



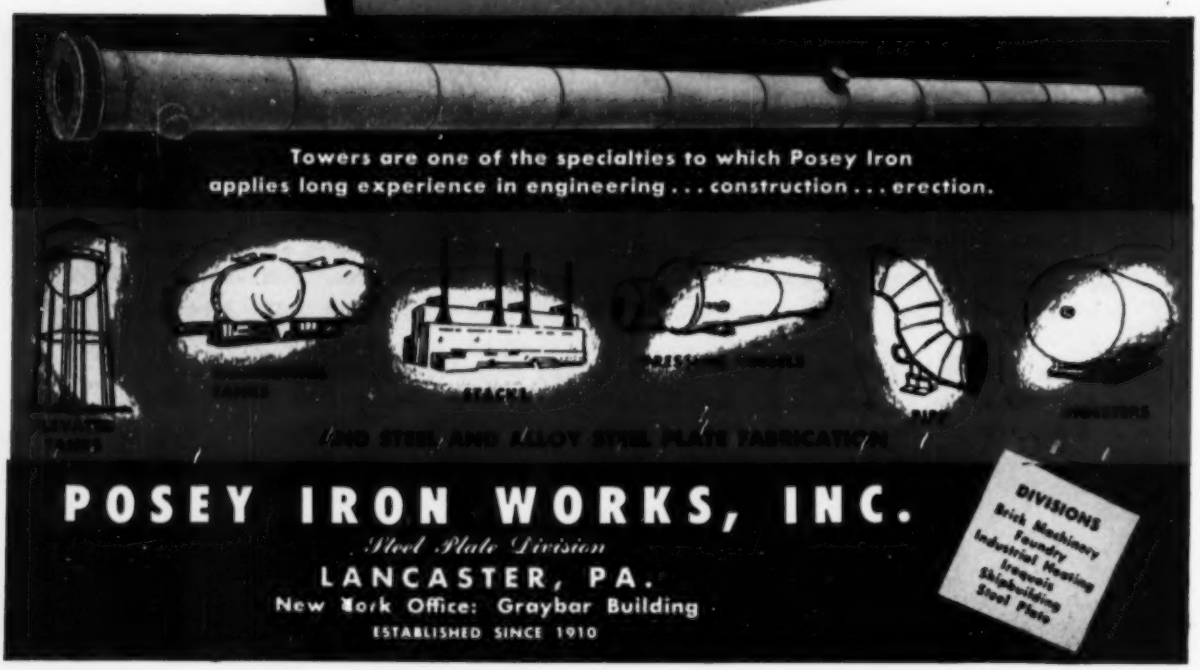
How To Cut Costs "Under Pressure"

What's the best time to cut your costs on any processing operation performed in a pressure vessel? Right at the beginning—at the time you buy the pressure vessel. Every day users in a wide variety of processing industries are saving money through the efficient performance of accurately engineered Posey Iron equipment.

Many Posey Iron pressure vessels are guaranteed not only for construction . . . but for performance as well. Posey Iron builds both large and small vessels . . . for liquids or gas. All are tested to considerable excess over normal working pressures.

Posey Iron meets all standard codes . . . including ASME; API-ASME; API. Welding receives special attention. Every welder in our shops is a fully qualified workman.

It pays to learn more about a proved, reliable supply source for pressure vessels which cut your processing costs through greater efficiency. Write today for free information about the Posey Iron Works' facilities and its installations in your industry.



Towers are one of the specialties to which Posey Iron applies long experience in engineering . . . construction . . . erection.

AND STEEL AND ALLOY STEEL PLATE FABRICATION

POSEY IRON WORKS, INC.

Steel Plate Division

LANCASTER, PA.

New York Office: Graybar Building

ESTABLISHED SINCE 1910

DIVISIONS
Brick Machinery
Foundry
Industrial Heating
Ingersoll
Shipbuilding
Steel Plate

Opinion and comment

THE YOUNG AT HEART

Chemical engineering is a profession for the young—regardless of years. It is for dreamers, but preferably for those who tend to be impatient for their dreams to come true. Best suited are persons of vigor, who use this quality in their willingness to try the "impossible" in fathoming their ways through boundaries of existing knowledge. These ways are more and more providing admission to Alice-in-Wonderland-like regions criss-crossed with paths having direction signs painted only in the strange language of nature, but offering, through the confusing maze, an occasional thrilling glimpse of the seemingly unattainable goal.

Evidence from many directions points to the important roles that young chemical engineers have attained in recent years. Equipment manufacturers often comment that never have they been asked by such *young* men to collaborate on producing items of such magnitude and capable of standing up to such extremes of operating service conditions. (The manufacturers seem to enjoy this situation, because of increased degree of participation.)

At a meeting held not long ago, which was attended by thirteen process executives from the same number of plants in a major industrial region, a questionnaire showed the average years of plant experience of these chemical engineers to be 10, with the range being from 5 to 15. In understanding the full significance of this, one should consider that the titles of these men run "head, engineering department; plant superintendent; chief engineer; chief process engineer; etc.," and that the plants involved are among the most complex, automatic and continuous operating today.

In citing this as significant information, it must be admitted that comparison is being made with prewar years. Then extensive plant experience was regarded as a most important qualification for advising management on important projects.

With the pressure of war, these plant-experienced men were quickly mustered into the initial expansion projects. Then men with less experience of such a character began to have their chance. We are all aware of the advances in theoretical chemical engineering that have taken place; these received their initial impetus from the war, but have continued at a high rate. As a result of these trends there has been a reaffirmation of the predepression faith in the near-miracles which lie ahead in chemical engineering. This time we should be converted for once and for all. We now know enough about vast unexplored fields, in contrast to our more blind faith of the twenties (which was, however, correct), to realize that the end of many major lines of development will not be seen during the lifetimes of most of us.

One of the curious and extremely heartening by-products of this aspect of chemical engineering is the way in which young men with their sound theoretical grounding have responded to the opportunities afforded them. They have proved their value. This is practically an understatement, inasmuch as the modern graduate has made such a record in arousing considerable doubt on how major developments of the future could be undertaken without his kind of service.

In many places, the *young* chemical engineer has dared to project his ideas through the medium of brilliant analyses based on sound and readily available theoretical procedures, has imbued his sponsors with his enthusiasm, and has undertaken prodigious tasks to make things work out as planned.

Though youth got its start during the last war because of manpower shortage, there seems little doubt that it has earned its place fairly and squarely. This puts us all on a basis of keeping up with *basic* developments, and endeavoring to keep youthful in our ideas, enthusiasm, and belief in the future.

Chemical engineering is without doubt for the "young at heart." As a bit of advice, better keep your eye on the fellow who goes about humming that popular tune. He's probably been converted to the philosophy and will be a real "stem winder" to keep up with, from now on.

J.B.M.

GRASS ROOTS

Chemical engineering plants, like their botanical counterparts, have many and varied roots. Of these, in the case of processing plants, among the most important are the *predecessor* plants. This has reference to new operating conditions and techniques derived from the experience gained from other plants.

As plants are often located close to sources of raw material and subsequent ones close to the original ones, this has created centers of processing activity. Among the more recent of these are Corpus Christi, Frankfort, Ashtabula, Pocatello, Pasadena, and a host of other interestingly named locations.

These centers of processing activity represent, in a sense, a proving ground for applied chemical engineering. It is here that theories are proved or disproved in the final analysis—which is the successfully or unsuccessfully operating plant. Often success or failure is based on smaller things, however, and in the newer processing centers, an active interchange of practical information having to do with problems in common has been noted.

These areas throughout the country are served by A.I.Ch.E. local sections, whose numerous professional and social activities include reporting their goings-on to C.E.P. These reports have appeared in the past under the title "Local Section News."

In recognition of the grass-roots position and functioning of the local sections, the name of the column in the magazine is being changed, and the context of the news carried is being expanded.

Beginning with this issue the new name is "News of the Field," with the subtitle "From the Local Sections." Local section secretaries and other correspondents are being asked to broaden the scope of their reportorial activities to include items of processing-community significance. Gradually, it is hoped to have this service functioning on such a basis as not only to provide interesting reading, but also to make a distinct contribution to applied chemical engineering communications.

J.B.M.

WELCOME TO A NEW EDITOR

A most important task in creating any new journal is finding the right editor. We know our members will be pleased to learn that Harding Bliss of the chemical engineering department of Yale University has agreed to become the editor of the new *A.I.Ch.E. Journal*, which is scheduled to make its first appearance this coming January.

Professor Bliss brings to the editorial post a varied and expert experience in all phases of chemical engineering, and we predict that under his guidance the new journal will become an important addition to the field.

The new editor will continue to carry a full schedule of classes at Yale and the profession is fortunate that an engineer of Bliss's standing has agreed to devote his free time to this cause.

We welcome him to the fourth estate and hope for him a long and happy experience therein. And we urge our membership to give him the cooperation, patience, and financial support which are all so necessary if a publication is to be successful.

F.J.V.A.

cut down on
drying expenses...with a
LOUISVILLE DRYER
by
General American

Louisville Rotary Cooler with rotary shell and external water sprays.

Louisville Rotary Steam-Tube Dryer —indirect type using steam as heating medium, and utilizing 85% of that steam for useful work.

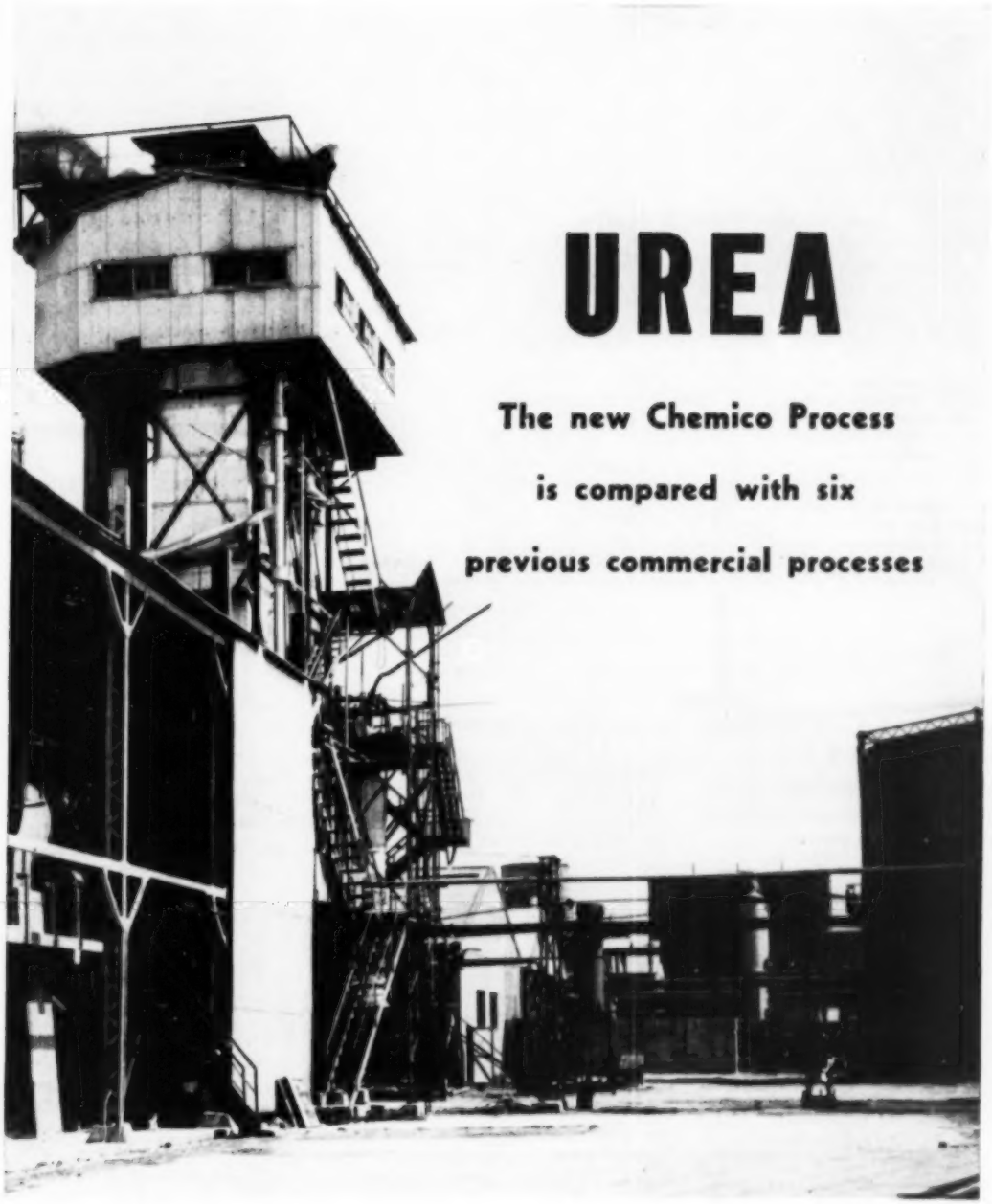
There is a LOUISVILLE DRYER for better drying in the following industries: Brewing • Canners By-Products Chemical • Distilling • Fertilizer • Fisheries • Feeds • Foods Mining • Packing House Products • Wood Products

LOUISVILLE DRYING MACHINERY UNIT
GENERAL AMERICAN TRANSPORTATION CORPORATION
General Offices: 135 South LaSalle Street, Chicago 90, Illinois
Dryer Sales Office: 139 S. Fourth Street, Louisville 2, Kentucky
OFFICES IN ALL PRINCIPAL CITIES

Know the results before you buy!

A Louisville engineer can tell you every saving, every improvement, every bit of increased efficiency *before* you invest. A Louisville Dryer is fitted to your job. It's the result of a Louisville engineer's complete analysis of your particular problem, of *knowing* your problem thoroughly... and solving it by applying 50 years of drying experience, and using the testing facilities of General American's laboratories.

More than once, a Louisville Dryer has turned a losing operation into a profitable one. Write or call for a Louisville engineer to make an obligation-free survey of your operation.



UREA

The new Chemico Process is compared with six previous commercial processes

L. H. Cook Chemical Construction Corporation, New York

Six complete recycle urea processes are described, each of which employs a different method of recovering and recycling ammonia and carbon dioxide obtained by decomposing unconverted carbamate. It is pointed out that the Du Pont, Montecatini, and the new Chemico processes use excess ammonia to increase the quantity of urea produced per pass, to reduce the amount of carbamate which must be decomposed, and to decrease the volume of ammonia and carbon dioxide which must be recovered and recycled.

The principal advantages claimed for the Chemico process are:

1. A 76% pass conversion of carbamate to urea by the use of excess ammonia, this conversion being almost twice that obtained with other commercially available processes.
2. A simple method of recovering and recycling excess ammonia by condensation with normal cooling water without the necessity of additional compression.
3. A simple method of recovering and recycling the ammonia and carbon dioxide obtained from carbamate decomposition; the quantities handled per ton of urea being much smaller than in other commercial scale processes.

The increasing demands of the plastics, feed, and fertilizer industries for synthetic nitrogen compounds have roused new interest in urea (*2*). World output of this, the cheapest solid form of nitrogen available, now exceeds 1,000 tons/day, and is expected to reach 2,000 tons in 1955 (*9*). Expansion at this rate will require improved manufacturing methods, greater efficiency and higher yields; and, to meet these needs, Chemical Construction Corporation has developed a new process of synthesizing urea, based on the fundamental ammonia-carbon dioxide reaction with a unique recycle modification. One version of the new method is in commercial operation at the Niihama, Japan, plant of the Sumitomo Chemical Co., which was designed by Chemico to produce 12 tons/day of urea.

Operating at conversion rates of 75-80% against approximately 40-50% for other commercially available processes, the Chemico method displays definite technical and economic advantages, which are emphasized by comparison with other processes. Therefore, in order to provide a proper basis for evaluating the Chemico procedure, a detailed review of the other major urea production processes is given here.

Review of Commercial Processes

BASIC ONCE-THROUGH PROCESS

The foundation of all modern commercial scale urea manufacture is the basic once-through process (Figure 1) in which the reaction of ammonia and carbon dioxide produces urea and water, with ammonium carbamate as the intermediate product. The raw materials, in the stoichiometric ratio of two moles of ammonia to one of carbon dioxide, react rapidly and completely in an autoclave operating at 160-200° C. and 120-200 atm. to form ammonium carbamate and heat, which is removed by a special heat-transfer surface in the autoclave (Reaction 1). Some of the carbamate then breaks down to urea and water (Reaction 2), the degree of conversion varying with autoclave operating conditions up to a maximum of 40-50%. The resulting mixture of urea, water and unconverted carbamate flows from the autoclave through a pressure-reducing valve into the carbamate decomposer. There, application of heat splits the carbamate into ammonia and carbon dioxide for use in a by-product fertilizer plant, where the ammonia is usually recovered as ammonium sulfate. The urea which is obtained by concentrating the aqueous solution from the decomposer is further purified by crystallization or prilling; then dried, cooled, bagged.

Recycle systems are modifications of the once-through process in which the ammonia and carbon dioxide from unconverted carbamate are recovered and returned to the autoclave for further reaction, thus eliminating the necessity of a by-product fertilizer plant. Six such modifications are described below.

HOT GAS RECYCLE PROCESS (6)

In this system the mixture of unconverted ammonia and carbon dioxide is compressed at high temperature (to prevent formation of solid ammonium carbamate in the compressor), and is returned to the autoclave. Make-up ammonia and carbon dioxide are added to

The various urea processes are illustrated in the flowsheets to the right. Intercommunicating bars are shown solely to indicate analogies between unit operations.

Fig. 3—
Equipment: 1 Autoclave; 2 Excess NH_3 separator; 3 1st carbamate decomposer; 4 1st absorber; 5 2nd carbamate decomposer; 6 2nd absorber; 7 NH_3 condenser; 8 solution pump.

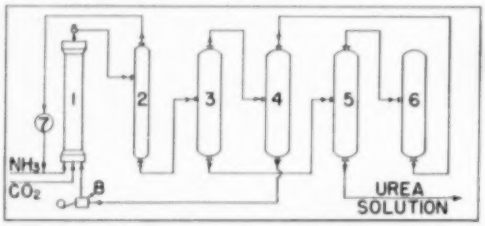


Fig. 3. Solution recycle process.

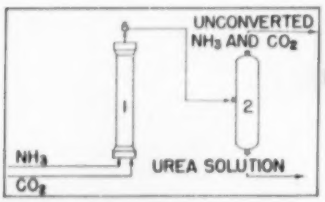


Fig. 1. Basic once-through process.

Equipment: 1 Autoclave; 2 Carbamate decomposer.
Reactions: (1) $CO_2 + 2NH_3 \rightleftharpoons NH_2COONH_4$ carbamate. (2) $NH_2COONH_4 \rightleftharpoons H_2O + NH_2CONH_2$ urea.

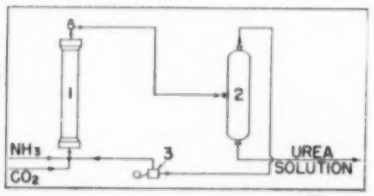


Fig. 2. Hot gas recycle process.

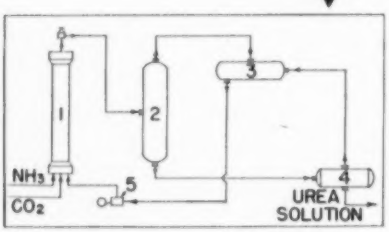


Fig. 4. Oil slurry recycle process.

Fig. 2—
Equipment: 1 Autoclave, 2 Carbamate decomposer, 3 Recycle compressor.

Fig. 4—
Equipment: 1 Autoclave; 2 Carbamate decomposer; 3 Slurry vessel; 4 Oil separator; 5 Slurry pump.

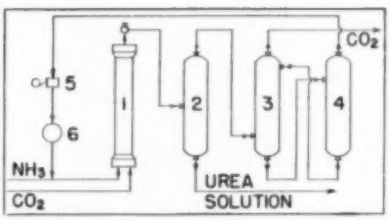


Fig. 5. Gas separation process—NH_3 absorption.

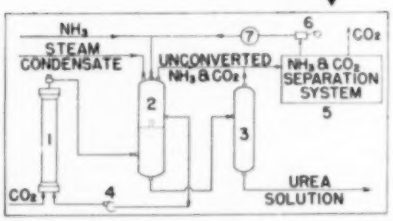


Fig. 6. Gas separation process-gas absorption.

Fig. 5—
Equipment: 1 Autoclave; 2 Carbamate decomposer; 3 NH_3 absorber; 4 NH_3 desorber; 5 NH_3 compressor; 6 NH_3 condenser.

Fig. 6—
Equipment: 1 Autoclave; 2 Combined expander-condenser; 3 Final carbamate decomposer; 4 Recycle pump; 5 NH_3 & CO_2 separation system; 6 NH_3 compressor; 7 NH_3 condenser.

the gas leaving the compressor at 260° C. and 130 atm. The resulting mixture, which is essentially dissociated ammonium carbamate at 220° C., passes through a cooler where the gases react to form liquid carbamate. The heat of this reaction is used to generate steam. (For the sake of simplicity the cooler is not shown in Figure 2.) The liquid carbamate at 160° C. and 120 atm. enters the autoclave and is partially converted to urea and water. The reaction product containing water, urea, and ammonium carbamate is fed under reduced pressure to the decomposer, where unconverted carbamate is dissociated to ammonia and carbon dioxide. This gas mixture is compressed and recycled as described here and the residual urea solution is then processed in a finishing section as explained.

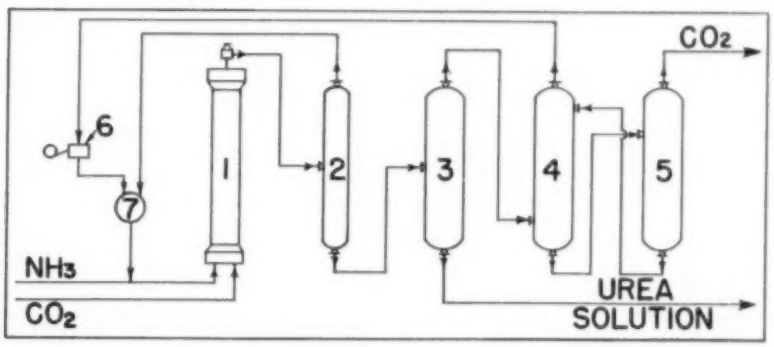


Fig. 7. Chemico process-gas separation process—CO_2 absorption.

Equipment:

1 Autoclave
2 Excess NH_3 separator
3 Carbamate decomposer
4 CO_2 absorber
5 Solvent regenerator
6 NH_3 compressor
7 NH_3 condenser

In using this process at its Oppau plant, I. G. Farben discovered two major disadvantages: it presented serious operating difficulties, and required constant maintenance work on the recycle compressors. Consequently, when the compressors were destroyed in World War II, the system was abandoned in favor of the basic once-through process.

SOLUTION RECYCLE PROCESS (5)

In this Du Pont process (Figure 3), the unconverted gases are returned to the autoclave as an aqueous ammoniacal solution of ammonium carbamate. Ammonia and carbon dioxide are added to give a combined feed ratio (mole basis) of 5 NH_3/0.73 H_2O/1 CO_2, which provides two and one-half times the stoichiometric amount of ammonia. Conversion of carbamate to urea reaches 70% in this system.

The reaction product consisting of urea, water, carbamate, and ammonia leaves the autoclave and flows under reduced pressure into the excess ammonia separator, which operates at 118° C. and 185 lb./sq.in.abs. The gaseous overhead from this separator, containing about 84% of the excess ammonia used in the reaction, is condensed and returned to a liquid ammonia storage tank. The mixture of urea, water, ammonia, and ammonium carbamate left in the separator is fed to the first carbamate decomposer, which passes on a fairly dry overhead of ammonia and carbon dioxide gases to the primary absorber. In a second decomposer the carbamate in the residue is dissociated and driven off together with free ammonia and water vapor. The aqueous urea solution which is left is sent to the usual finishing operations. The overhead goes to a secondary absorber where an aqueous ammoniacal solution of ammonium carbonate is formed as the water condenses and the carbon dioxide and ammonia are reabsorbed. This solution is pumped to the primary absorber where it is brought into contact with the overhead gas from the primary carbamate decomposer. Water in the decomposer is condensed, and the ammonia and carbon dioxide are absorbed. The resulting aqueous solution containing ammonia and ammonium carbamate is pumped into the autoclave for reprocessing.

OIL SLURRY RECYCLE PROCESS (PECHINEY PROCESS)

The oil slurry recycle method developed by the Chemical Electro Metallurgical Products Co. of St. Auban, France, is illustrated in Figure 4 (*7, 8*). Unconverted gases leaving the top of the carbamate decomposer are mixed with oil in a slurry vessel, and react to form a suspension of fine particles of ammonium carbamate in the agitated oil. This slurry is then recycled by pumping it into the urea autoclave. Besides serving as a vehicle for recycle carbamate, the inert oil also acts as a medium for heat transfer. The oil entering the autoclave is heated to autoclave temperature by the exothermic heat of reaction, and when the autoclave effluent reaches the decomposer the heat carried by the oil is utilized in the endothermic dissociation of ammonium carbamate (Reaction (*2*). The slurry, together with make-up liquid ammonia and gaseous carbon dioxide in the ratio of 2 moles NH_3/1 mole CO_2, is fed to the autoclave, which operates at 180° C. and 200 atm. Following the reaction, in which a 50% conversion of carbamate to urea is attained, the autoclave effluent of urea, water, carbamate, and oil flows at reduced pressure into the decomposer. There, unconverted carbamate dissociates to gaseous ammonia and carbon dioxide, to be recovered and recycled; the residue goes to the oil separator. The oil is recovered there and is pumped back to the slurry vessel for reuse. The urea solution left in the separator is centrifuged to remove the last traces of oil, concentrated in an evaporator, and treated in the usual finishing operations.

GAS SEPARATION RECYCLE PROCESS—AMMONIA ABSORPTION (3)

The Hovag Company of Switzerland developed this method (Figure 5), better known as the Inventa Process, in which the gaseous mixture of unconverted ammonia and carbon dioxide leaving the carbamate decomposer is routed to an absorber, where aqueous urea nitrate solution absorbs the ammonia (*4*). The carbon dioxide overhead is either vented to the atmosphere or recycled. Ammonia is stripped from the solution in a desorber; it is then compressed, liquefied and recycled to the autoclave. The regenerated urea nitrate solution is returned to the ammonia absorber.

The autoclave, operating at 180-200° C. and 200 atm. is charged with liquid ammonia and gaseous carbon dioxide in a mole ratio slightly higher than 2:1 to give a small excess of ammonia. Heat-transfer surface is provided in the autoclave to facilitate generation of steam by the heat of carbamate formation. After carbamate-to-urea conversion reaches a maximum of 50%, the autoclave effluent of urea, water, and unconverted carbamate runs through a pressure-reducing valve into the decomposer, where the carbamate is broken

down to ammonia and carbon dioxide. The unconverted gases are extracted for recycle as described above, and the residual urea solution is drained from the decomposer, concentrated, and given the usual finishing treatment.

GAS SEPARATION PROCESS—GAS ABSORPTION (1)

Data on this Montecatini Process (Figure 6) are still scarce, since the Process is only now being introduced in the United States. From the available information it would seem that the gaseous mixture of ammonia and carbon dioxide leaving the carbamate decomposer is sent to an absorber, where an undisclosed solvent absorbs one of the two gaseous components, the other going overhead to be vented or recycled. The absorbed constituent is presumably stripped from the solution in a desorber for possible recycling, with the regenerated selective solvent returning to the absorber. Operating with excess ammonia, the process is said to attain a carbamate-to-urea conversion of 70%.

The autoclave product containing urea, water, carbamate, and excess ammonia flows at reduced pressure into the bottom of a combined expander condenser. Application of heat in the expander section drives off excess ammonia from the autoclave effluent. Some carbon dioxide also goes overhead with the ammonia. This overhead gas mixture enters the condenser section above the expander, where it is brought into contact with steam condensate and make-up ammonia for the reaction. Liquid ammonia condenses most of the excess ammonia coming from the expander, and steam condensate absorbs most of the carbon dioxide as carbamate. Uncondensed ammonia and carbon dioxide are taken off overhead and added to the decomposer overhead; the resulting gas mixture is sent to the gas separation section previously described. The liquid product formed in the condenser, which consists of ammonia and aqueous ammonium carbamate, is withdrawn from the bottom of the condenser and pumped into the autoclave together with gaseous carbon dioxide.

The residue from the expander bottom flows to the decomposer, where unconverted carbamate is dissociated to ammonia and carbon dioxide to be fed to the gas separation system. The bottoms from the decomposer, essentially an aqueous urea solution, can then be sent to the usual finishing operations.

Chemico Process—Carbon Dioxide Absorption

The Chemico Urea Process (Figure 7) utilizes a carbon dioxide-absorption gas separation system for recycling gases obtained from unconverted carbamate.

Ammonia and carbon dioxide expelled from the carbamate decomposer are separated in an absorber, where a monoethanolamine solution absorbs the carbon dioxide selectively from the mixture leaving a gaseous ammonia overhead to be compressed, liquefied, and stored. The carbonated solvent is transferred from the bottom of the absorber to a solvent regenerator for desorption of the carbon dioxide, which is then recycled to the autoclave. The regenerated solvent is returned to the top of the carbon dioxide absorber.

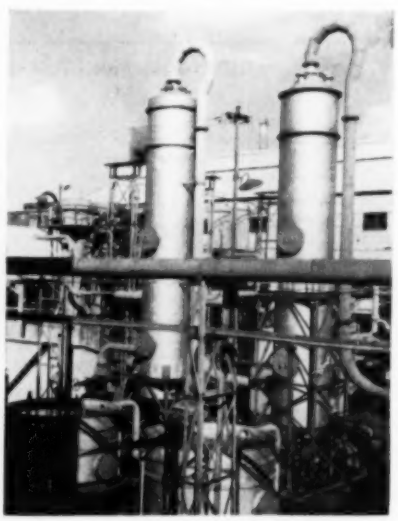
Liquid ammonia and carbon dioxide in a 6:1 mole ratio are charged to a urea autoclave operating at 175-185° C. and approximately 170 atm. The 200% excess of ammonia under these conditions increases the theoretical conversion of carbamate to urea from 48% to 83%; actual conversion is about 76%. The heat produced in the carbamate-forming reaction serves to bring the excess ammonia to reaction temperature, thus obviating the need for heat-transfer surface in the autoclave.

The autoclave effluent consisting of urea, water, unconverted ammonium carbamate, and excess ammonia flows under reduced pressure to the separator, where distillation removes 98% of the excess ammonia as a dry gas, free of carbon dioxide. The dry, pure ammonia vapor is then liquefied by condensation with available cooling water. (Prior removal of carbon dioxide prevents the formation of solid ammonium carbamate, which would clog the condenser.) The residue of urea, water, free ammonia, and unconverted carbamate leaving the bottom of the excess ammonia separator is fed at reduced pressure to a decomposer. There the carbamate is transformed to a gaseous mixture of ammonia and carbon dioxide, which can then be treated in the carbon dioxide absorber by the method described in the preceding paragraph. The aqueous urea solution left in the decomposer is evacuated, concentrated in an evaporator, and sent to the usual finishing operations.

The economic advantage of operation with excess ammonia can best be illustrated by comparing the Chemico process and a process using the same recovery system without excess ammonia. Theoretical conversion of carbamate to urea reaches 83% at 175° C. in the presence of 200% excess ammonia; with stoichiometric proportions of ammonia and carbon dioxide, theoretical conversion is only 48%. With the excess, 74% more ammonia must be pumped into the autoclave, and additional equipment is required to separate and condense the surplus ammonia. However, these factors are outweighed by an 80% reduction in the quantity of ammonium carbamate to decompose, ammonia to compress, and gas to separate. The amount of carbon dioxide which must be compressed, purified, condensed and pumped is reduced by 42%, and no heat-transfer surface is needed in the autoclave. The final overriding consideration is the significant increase in per pass conversion of carbamate to urea—from 48% with the stoichiometric feed ratio to 75% with a 200% excess of ammonia. Economic evaluation of these factors reveals that the excess ammonia system is markedly superior to the stoichiometric feed system in terms of equipment needs, work input and yield.

Plant Investment

Urea plant investments reported in the literature range from $12,000 to $30,000/daily ton, varying with the type of process used, plant capacity, and plant location. For a complete recycle Chemico plant capable of producing 150 tons of bagged urea per day, the investment required is approximately $20,000/daily ton, or three million dollars. This figure is based on the cost of an erected plant with all necessary process equipment, instruments and controls; utility piping and controls, and buildings and foundation. Paid-up royalties, training of operating personnel, and supervision of initial start-up are also included in this price.



When such a plant is to be installed adjacent to an existing fertilizer unit, as at Sumitomo, where there is an ammonium sulfate plant using gaseous ammonia as a raw material, the investment required decreases by about 20%, roughly to two and a half million dollars. In this case there is no need to install an ammonia recovery system, since the mixture of unconverted ammonia and carbon dioxide leaving the decomposer is separated in the fertilizer plant. Even in this type of partial recycle plant, how-

Table 1.—Operating Requirements

Materials	
Liquid NH_3	0.585 tons
CO_2 Gas	0.773 tons
Solvent Make-Up	0.033 lb.
Bags (100-lb. bags)	20 bags
Utilities	
Electric Power	250 kw.-hr.
Circulating Cooling Water	22,000 gal.
Steam, 150 lb./sq.in. gauge	6,000 lb.
Operating Labor	1.12 man-hours

ever, excess ammonia is used to insure high carbamate conversion.

Operating Requirements

Operating requirements per ton of urea for a complete recycle Chemico urea plant producing 150 tons of urea/day are shown in Table 1.

Acknowledgment

The author wishes to express his appreciation to Chemical Construction Corporation for granting permission to make public certain details of the Chemico urea process, and to the Sumitomo Chemical Company of Japan for its valuable technical assistance in the development of the process.

Literature Cited

1. M. W. Kellogg Bulletin, "Montecatini Ammonia-Saturated Urea Process."
2. Berliner, J. F. T., *Ind. Eng. Chem.*, **28**, No. 5, 517-522 (1936).
3. Bland, W. F., *Petroleum Processing*, **7**, No. 10, 1457-1460 (1952).
4. Cramer, C., U. S. Patent 2,634,826 (April 14, 1953).
5. de Ropp, H. W., U. S. Patent 2,116,881 (May 10, 1938).
6. Dewling, W. L. E., and J. Robell, "Urea Manufacture at the I. G. Farbenindustrie Plant, Oppau," Hobart Publishing Co., Washington, D. C.
   FIAT Report No. 889; PB Report No. 47773.
7. Frejacques, M., *Chem. Ind.*, **60**, No. 1, 22-35 (1948).
8. Rooseboom, A., *Chem. Eng.*, **58**, No. 3, 111-114 (1951).
9. Unpublished Report, Market Survey "Urea."

Discussion

Anonymous (George Washington University): What is the comparative cost per unit of nitrogen to produce urea as against ammonium nitrate? Can you give me a percentage figure on that?

Lucien Cook: Cost per ton of urea nitrogen is competitive with cost of nitrate nitrogen.

Tucker (Columbia-Southern Chemical Company): You mentioned that the investment cost was lower by 20% when you ran it onto a fertilizer plant. Is that figure the same for operating cost?

L. Cook: No; operating cost does not vary directly with investment cost. However, operating cost in a partial recycle plant is somewhat lower than in a complete recycle plant.

Tucker: Would there be much of a saving if you didn't recycle that excess ammonia?

L. Cook: It is more economical in any case to recycle the excess ammonia whether or not the recovery system is used.

Tucker: I would assume that the part where you recycle the excess ammonia is covered in patents.

L. Cook: The recycle ammonia separator, including the recovery system on the end, is covered by patent applications.

D. L. Caldwell (Foster Wheeler): In stating your percentage improvements you didn't make clear the base case you were comparing.

L. Cook: I was basing it on operation without excess ammonia. I compared the figures on a theoretical basis, and I said that our process, with excess ammonia, would have one fifth as much carbamate to dissociate and from there on, down the line, as against the same process not using excess ammonia.

D. L. Caldwell: There are other recycle processes that do not recycle carbon dioxide as such, but in the form of carbamate. You said you handled less carbon dioxide than used in other processes; that presumably must be in the form of carbamate and not carbon dioxide as such.

L. Cook: I said that in the Chemico process only 58% as much carbon dioxide must be compressed, purified, condensed, and pumped as in processes using no excess ammonia. This refers to carbon dioxide entering the autoclave in any form per ton of urea produced. In a case where carbon dioxide is fed as carbamate or carbonate, only the make-up need be compressed. With a 6:1 ammonia:carbon dioxide feed ratio (mole basis) and 76% conversion, 0.76 mole of urea is produced/mole of carbon dioxide fed to the autoclave. This is equivalent to 0.965 tons of carbon dioxide/ton of urea produced. However, with a 2:1 ammonia:carbon dioxide ratio (mole basis) and 45% conversion, 0.45 mole of urea is produced/mole of carbon dioxide fed to the autoclave. This is equivalent to 1.63 tons of carbon dioxide/ton of urea produced. Therefore, it is evident that the use of excess ammonia requires only 58% as much carbon dioxide handling per ton of urea.

E. N. Martenson (Swift & Company): I'm interested in what carbon dioxide make-up costs per ton.

L. Cook: A urea plant is most likely to be located adjacent to an ammonia plant from which carbon dioxide can be obtained at no cost. If, however, urea is to be made from purchased ammonia, a source of carbon dioxide such as stack gas must be available; in this case, cost of separating the carbon dioxide from the stack gas would be about $3.00/ton of carbon dioxide.

M. E. Miller (Mathieson Chemical Corporation): Did you encounter much trouble in the separation of carbamate solids from the liquid ammonia in the top of the tower? I have the impression that the carbamate is relatively insoluble in liquid ammonia if the temperature is too low.

L. Cook: Carbamate is relatively insoluble in liquid ammonia. However, we operate our tower at a temperature at which carbon dioxide condenses as carbamate, which is returned to the bottom of the column in the small amount of water which continually refluxes.

M. E. Miller: On what scale has the process you are describing been operating?

L. Cook: In the plant in Japan, we started with a 40 ton/day installation, which has since been expanded to 120 tons/day. The plant went into operation in October, 1952.

R. Katzen (Consultant): What do you find with regard to corrosion in your excess ammonia system?

L. Cook: As far as materials of construction are concerned, Sumitome tested a wide range of metals and alloys in 500-hr. runs in liquid and gas phases. As a result of these tests, we have selected an alloy with a long life as a backing for the silver lining we use in the autoclave. Lead is sometimes recommended as an autoclave liner. However, it has been found in practical operation that a lead liner is difficult to hold in place even at temperatures as low as 175° C. Constant maintenance is required. In view of this experience, it is hard to understand how lead liners can perform satisfactorily at 220° C., although the literature mentions such an application. Nickel-chrome alloys are unsuitable, because urea contaminated with chromium is not acceptable for plastics-grade.

G. L. Bridger (Iowa State College): How much hydrogen sulfide can you stand in the carbon dioxide being used in this process?

L. Cook: We use activated carbon to remove the last traces of sulfur, and platinum catalyst to remove oxygen. Inert gases are removed when the carbon dioxide is condensed.

Presented at A.I.Ch.E. Washington, D. C., meeting.

Census

of equipment scale-up practice

To broaden the scope of their Springfield paper, the authors quizzed 250 A.I.Ch.E. members engaged in process design.

Laurent Michel, Robert D. Beattie, and T. H. Goodgame — Godfrey L. Cabot, Inc., Cambridge, Massachusetts

For twelve pieces of equipment, representing seven unit operations, limits of extrapolation for use in process design have been established. These scale-up ratios, the defining characteristics, and the required safety or overdesign factors are presented to indicate the size and desirability of pilot-plant equipment. The conclusions presented are based on a survey of process engineers.

Among the pertinent factors involved in the decision to pilot a process are extrapolation limits of data, reliability of data required for plant scale design, and the safety factor for inaccuracies in design. The effects of chemical reactions and corrosion are omitted because these factors would make the work too specific. It is the purpose of this paper to provide generalized answers for twelve selected kinds of equipment.

To provide a representative cross section of the operations encountered in chemical engineering practice, data were obtained for the following types of equipment: plate and frame filters, rotary filters, centrifugal pumps, reciprocating compressors, screw conveyors, hammer mills, shell-and-tube heat exchangers (liquid-liquid), spray condensers, plate columns, packed columns, cooling towers, and cyclones.

Any results are of greater value to chemical engineers if based on the experience of many engineers rather than on the experience of a single group, especially if this group is not actively engaged in equipment design. Accordingly, multiple-choice questionnaires were sent to 250 chemical engineers who are Active members of the American Institute of Chemical Engineers and who are engaged in process design. Answers received from approximately 40% of these engineers are the data presented.

A sample questionnaire for plate columns is reproduced here. This self-explanatory questionnaire is representative of those used for all twelve pieces of equipment. The number of usable answers to each question and the percentage distribution of answers among the multiple choices are also shown. Answers received to questionnaires dealing with the other pieces of equipment are given in Table 2.

From this tabulation the best answers to questions 1, 2, and 3 were determined; the best answers to questions 4 and 5 were found by statistical methods. The results of this interpretation are shown for all twelve pieces of equipment (Table 1). Although the results are the composite judgment of qualified design engineers, they should be used with reasonable limitations and should be modified where chemical reactions or unusual conditions of construction or operation exist.

A pilot plant is recommended in only three cases, all of which involve processing of solids (*see* Table 1: plate and frame filters, rotary filters, and hammer mills).

The column headed *design variable* shows which operational data are most important. Although in every case one item was outstanding, it was noted repeatedly that other variables were almost as important.

Distribution plots of answers to question 4 in the sample questionnaire below were characterized by two maxima. The first peak was interpreted as an average scale-up ratio based on the characterizing variable; the second peak as a maximum scale-up ratio based on flow rate. Both sets of answers are shown in Table 1.

The best value for safety factor is the single peak in a frequency-vs.-size plot of answers to question 5. The range suggested is the heart cut (35 to 65%) of a plot of safety factor vs. cumulative percentage of answers.

Finally it may be of interest to know that based on the questionnaires returned signed (no signatures were requested) no significant differences were found between answers from design company personnel and answers from operating company personnel. It would not have been surprising if there had

SAMPLE QUESTIONNAIRE: PART TWELVE PLATE COLUMNS

Usable Answers

1a. With only the following data on the desired operation: X-Y data (vapor pressures or K factors), liquid and vapor densities, liquid viscosities, surface tension, flow rates, feed, overhead and bottoms analyses, is it in your opinion possible to design successfully a plant-scale plate column?

79 Yes 90% No 10%

1b. Or is it necessary to go through a pilot-plant stage?

73 Yes 10% No 90%

2. For a given flow rate, please check the item which is of most importance in your design of a plate column:

X-Y data 75%, liquid viscosity 0%, surface tension 0%,

72 superficial vapor velocity 14%, slot velocity 1%, pressure 2%,

other 3%

3. In the scale up from one flow rate to another, check the item which most clearly characterizes the size or capacity of a plate column:

diameter 94%, plate spacing 1%, number of plates 3%, reflux

70 ratio 1%, other 1%

4. What scale up ratio of the characterizing variable is the maximum generally allowable for plant design?

None 3%, 2:1 0%, 5:1 13%, 10:1 25%, 20:1 6%, 50:1 5%

69 100:1 9%, 100:1 42%

5. What safety or overdesign factor is necessary to account for changes in operating performance with time?

63 0 19%, 2% 3%, 5% 2%, 10% 46%, 25% 31%, 50% 2%, 50% 0%

6. Comments

been differences, particularly in safety factors required.

Equipment

For each type of equipment there are other more specific limitations, which are discussed below.

PLATE AND FRAME FILTERS

A pilot plant is usually required but can often be replaced by experience on materials with similar characteristics or by manufacturer's tests. Cake resistance (permeability), solids concentration (in recovery of solids as opposed to clarification operations), and compressibility of cake are important variables contributing to filter design.

ROTARY FILTERS

As in the foregoing case, where experience or manufacturer's tests cannot be used to extrapolate cake resistance (permeability) and compressibility under desired operating conditions, a pilot plant is usually required.

CENTRIFUGAL PUMPS

In addition to required power input and impeller diameter, a useful characteristic in scale-up is specific speed.

RECIPROCATING COMPRESSORS

Either piston displacement or required power input may be used as the characterizing variable. In actual practice, overdesign may approach 50% to allow excess capacity (specifically true for service units).

SCREW CONVEYORS

A pilot plant is not required for conveying standard products, but it or manufacturer's tests are necessary if unusual conditions such as stickiness, packing tendency, contamination, poor material strength, etc., are encountered.

Although bulk density is presumably the primary design variable for the average case, other variables may have a modifying effect. Diameter is the most useful characteristic for scale-up.

Generally a safety factor between 8 and 21% is recommended; this is the largest of any in Table 1. Because of varied service and the number of unusual applications, an average case may be difficult to visualize. In addition, screw conveyors are often overdesigned by as much as 50 to 100% to allow for process revisions.

HAMMER MILLS

For materials where no previous experience is available, pilot-plant tests are recommended. These can often be performed by the manufacturer provided test equipment is large enough. The purpose of these tests is usually to control the amount of fines produced for a given size reduction.

SHELL-AND-TUBE HEAT EXCHANGERS (LIQUID-LIQUID)

Pilot-plant tests are rarely required except for severe fouling conditions. Temperatures, since they affect thermal conductivities, specific gravities, and specific heats, are most important in design. The 14% safety factor is an average allowance for fouling tendency, as usually no safety factor for assumptions in design is needed.

SPRAY CONDENSERS

Latent heats of vaporization and temperature in that order are primary data required for successful design. Characteristics of the spray nozzles used and the amount of noncondensables are also pertinent design problems.

PLATE COLUMNS

Where there are unusual fouling conditions or where the equilibrium data are inaccurate, a pilot plant may be needed, but generally a pilot plant is not necessary. *X-Y* data and superficial vapor velocity are both important for design, since *X-Y* data determine column height, and vapor velocity (vapor load) determines column diameter.

Allowable scale-up ratio of column diameter is often limited by consideration of maximum equipment size (maximum column diameter is near 20 ft.) rather than by the validity of the extrapolation.

The distribution of safety factors reflects three causes (*see* sample questionnaire): (1) fouling tendencies may require an overdesign as high as 50%, (2) commercial practice usually allows excess capacity for expected increased production, and (3) sometimes reflux ratios are purposely set at conservative levels to account for changes in operating performance.

PACKED COLUMNS

The comments given above are also valid for packed columns. Pilot-plant operation is performed more frequently because experience is more limited. Superficial-vapor velocity and height to diameter ratio assume increased importance in design and scale-up respectively. Column diameters over 6 ft. are rarely encountered.

Table 1.— Consolidated Answers to Questionnaire

Name of Equipment	Is Pilot Plant Required	Design Variable	Characteristic Variable	Scale-up Ratio Based on Charact. Variable	Scale-up Ratio Based on Flow Rate	Safety Factor Best Value %	Safety Factor Range %
Plate and Frame Filters	Yes	Cake resistance or permeability	Filtration area	>100:1	>100:1	18	11-21
Rotary Filters	Yes	Cake resistance or permeability	Filtration area	25:1	>100:1	19	14-20
Centrifugal Pumps	No	Discharge head	Power input	>100:1	>100:1		
			Impeller diameter	10:1	>100:1	10	7-14
Reciprocating Compressors	No	Compression ratio	Power input	>100:1	>100:1		
			Piston displacement	>100:1	>100:1	9	7-14
Screw Conveyors	No	Bulk density	Diameter	8:1	90:1	18	8-21
Hammer Mills	Yes	Size reduction	Power input	60:1	60:1	19	15-21
S & T Liquid Heat Exchangers	No	Temperatures	Transfer area	>100:1	>100:1	14	11-18
Spray Condensers	No	Latent heat vaporization Temperatures	Height to diameter ratio	12:1	70:1	22	18-24
Plate Columns	No	X-Y data	Diameter	10:1	>100:1	13	10-16
Packed Columns	No	X-Y data	Diameter	10:1	>100:1	15	11-18
Cooling Towers	No	Air humidity	Volume	10:1	>100:1	15	12-20
Cyclones	No	Particle size	Diameter of body	3:1	10:1	10	7-11

Table 2.—Consolidated Raw Data

Equipment	Is Pilot Plant Required		Design Variable		Characteristic Variable		Scale-Up Ratio		Safety Factor	
									%	
Plate & Frame Filters	Yes	25	Cake resistance or permeability	28½	Total filtration area	40½	None	4	0	3
	No	22	lbs. solids/cu.ft. fluid	10½	Volume available for cake	3½	2:1	2	2	0
			Cake compressibility	4½	No. of plates & frames	2	5:1	2	5	6
			Viscosity of fluid	1	Size of plates & frames	1	10:1	3½	10	10
			Shape of cake particles	0	Other	0	20:1	2½	25	18
			Other	2			50:1	5	50	1
							100:1	5	>50	0
							>100:1	16		
Rotary Filters	Yes	36	Cake resistance or permeability	30	Total filtration area	42	None	4	0	2
	No	19	lbs. solids/cu.ft. fluid	8	Speed of rotation	4	2:1	2	2	0
			Cake compressibility	2	Diameter of filter	0	5:1	2	5	1½
			Viscosity of fluid	1	Width of filter	0	10:1	4	10	13½
			Shape of cake particles	0	Other	1	20:1	7	25	20
			Other	7			50:1	2	50	1
							100:1	6	>50	0
							>100:1	16		
Centrifugal Pumps	Yes	1	Discharge head	33	Power input	26½	None	1	0	1
	No	63	Viscosity	5	Impeller diameter	19½	2:1	2	2	0
			Suction head	4	Size of discharge opening	5	5:1	0	5	16½
			Density	1	RPM	3½	10:1	13	10	23½
			Vapor pressure	1	Size of suction opening	3	20:1	1	25	15½
			Temperature	½	Other	2	50:1	2	50	1
			Other	14½			100:1	8	>50	0
							>100:1	20		
Reciprocating Compressors	Yes	2	Compression ratio	45½	Piston displacement	30½	None	1	0	2
	No	63	Cp/Cv ratio	5	Power input	28	2:1	5	2	5½
			Molecular weight of gas	2	RPM	½	5:1	1	5	12½
			Liquefaction conditions	½	Other	1	10:1	8	10	28½
			Initial temperature	0			20:1	0	25	9½
			Other	5			50:1	3½	50	0
							100:1	3½	>50	0
							>100:1	28		
Screw Conveyors	Yes	10	Bulk density	23	Diameter	29½	None	4	0	10
	No	38	Sieve analysis	5	Drive H.P.	12	2:1	3	2	0
			Angle of repose	5	RPM	3½	5:1	4	5	3
			Material density	3	Other	2	10:1	10½	10	11½
			Other	10			20:1	1½	25	12½
							50:1	2	50	7
							100:1	8	>50	0
							>100:1	3		
Hammer Mills	Yes	24	Size reduction	16	Total H.P. input	26	None	0	0	2
	No	16	Grindability index	12	Rotor diameter	6	2:1	5	2	0
			Final size	6	Number of hammers	1	5:1	7	5	1
			Initial size	0	Other	1	10:1	5	10	13
			Other	2			20:1	3	25	19
							50:1	10	50	2
							100:1	2	>50	0
							>100:1	4		
S & T Liquid Heat Exchangers	Yes	4	Temperatures	27½	Total transfer area	61	None	4	0	2¼
	No	71	Viscosities	13½	Reynolds No.	5½	2:1	0	2	0
			Thermal conductivities	11½	Prandtl No.	2	5:1	1	5	6½
			Specific heats	1½	Tube diameter	0	10:1	9	10	29¼
			Other	10	Tube length	0	20:1	1½	25	20¾
					Number of tubes	0	50:1	7	50	1¾
					Other	4½	100:1	7½	>50	1
							>100:1	32		
Spray Condensers	Yes	2	Latent heats of vaporization	18½	Height to diameter ratio	17	None	0	0	3
	No	45	Temperatures	14½	Liquid rate	9	2:1	1	2	0
			Vapor superheat or quality	2½	Tank volume	8	5:1	0	5	1
			Thermal conductivities	1	No. of spray heads	3	10:1	12	10	7
			Specific heats	0	Other	1	20:1	3	25	27
			Viscosities	0			50:1	12	50	1
			Other	7½			100:1	5	>50	1
							>100:1	3		
Plate Columns	Yes	7	X-Y data	53⅝	Diameter	65½	None	0	0	12
	No	66	Superficial vapor velocity	13⅝	No. of plates	1⅝	2:1	0	2	0
			Pressure	1½	Plate spacing	1	5:1	8	5	1½
			Slot velocity	½	Reflux ratio	⅝	10:1	16	10	29
			Liquid viscosity	0	Others	1	20:1	4	25	19½
			Surface tension	0			50:1	3	50	1
			Other	2½			100:1	6	>50	0
							>100:1	27		

Table 2 (Continued).

Equipment	Is Pilot Plant Required		Design Variable		Characteristic Variable		Scale-Up Ratio		Safety Factor %	
Packed Columns	Yes	18	X-Y data	45½	Diameter	55½	None	2	0	12
	No	56	Superficial vapor velocity	14	Height to diameter ratio	8½	2:1	7	2	0
			Liquid velocity	2½	Packed height	1½	5:1	16	5	2
			Liquid viscosity	1½	Other	2½	10:1	16½	10	26
			Pressure	1			20:1	7½	25	26
			% void space	½			50:1	4½	50	2
			Surface tension	0			100:1	4	>50	0
			Other	7			>100:1	9		
Cooling Towers	Yes	3	Air humidity	30	Volume	39	None	3	0	3
	No	59	Degree water temperature to be lowered	9½	Height to width ratio	6	2:1	3	2	0
			Inlet water temperature	4	Length	5	5:1	1	5	3
			Outlet water temperature	1	Height	0	10:1	10	10	26½
			Air temperature	½	Width	0	20:1	2	25	16½
			Other	11	Other	5	50:1	3½	50	1
							100:1	5½	>50	0
							>100:1	19½		
Cyclones	Yes	16	Particle size	48½	Diameter of body	49½	None	2	0	11
	No	46	Product density	5	Diameter of inlet	2	2:1	10	2	3
			Grain loading	2	Diameter of outlet	1	5:1	6	5	9
			Other	5½	Overall length	1	10:1	17	10	20
					Other	4½	20:1	6	25	10
							50:1	3	50	1
							100:1	2	>50	1
							>100:1	2		

A slightly higher safety factor is suggested because fouling may be more important, and error in design is often as high as 10%.

COOLING TOWERS

Air humidity is the primary consideration in design, although related data, e.g. wet-bulb temperature, are sometimes preferred. Tower volume is the best scale-up characteristic, but height-to-width ratio and length of cells are also important.

CYCLONES

Solids (or liquids) which require agglomeration before collection, for example carbon black, demand pilot-plant study. In this case factors affecting the agglomeration rate, for instance temperature, are critical and will determine the necessity for a pilot plant rather than the cyclone design itself.

Illustrative Example

The plant received granular solids in bulk in hopper cars; an air conveying system including a cyclone collector was indicated to transfer the material to storage. Operating data on a 9-in. I.D. cyclone performing an equivalent job, although at a lower flow rate, viz. 330 cu.ft./min., are available. However, the expected air conveying flow rate is 1,800 cu.ft./min. (1,640 cu.ft./min. rated blower output plus 10% safety factor). As the material was agglomerated; the scale-up ratio based on flow rate was 1800/330 = 5.45, that is, less than 10:1; and the scale-up ratio based on diameter was 21/9 = 2.33, or less than 3:1, a 21-in. I.D. cyclone was installed without further experimental work and with a substantial saving in research time and dollars.

Later a cyclone was needed to collect at 600° F. a very fine product of which the agglomerating tendencies were not known. Operating data were available using the same 9-in. I.D. cyclone handling 330 cu.ft./min. at 80° F., and the expected flow rate was again 1,800 cu. ft./min. Even though the scale-up ratios were within the suggested range, the effect of change in temperature on agglomeration, i.e., on collection efficiency, is such that further tests at 600° F. using a cyclone handling at least 1800/10 = 180 cu.ft./min. were recommended.

Conclusions

This paper was intended to help decide the necessity for pilot-plant experiments on the operation of specific types of equipment. Subject to the limitations discussed in the text, an answer is given in Table 1. Pilot-plant tests are not needed if the characteristics of the materials to be processed are known or can be accurately extrapolated; for unknown materials or new processes, pilot plants are often needed.

It may be concluded that the chemical (more often than the equipment) aspects of a process dictate the need for a pilot plant. Hence the function of a pilot plant may be to determine the characteristics of an intermediate or final product and/or to provide the product necessary for market development rather than to determine the performance of a given piece of equipment. Consequently successful equipment design is not a major criterion for construction of a pilot plant.

The economics of pilot plants are pertinent to this discussion since they are related to the overdesign factor. Assuming a market sufficiently stable so that no safety factor is required for process changes, pilot plant experiments reduce the required safety factor. This saving may be significant for large equipment, but not worth while for small equipment where extra capacity can be purchased for an incremental increase in capital cost. No matter what the case, it is not good design unknowingly to overdesign a piece of equipment by 100% and then to extoll the virtues of the design because equipment capacity is twice the design rate.

This paper has also shown the extrapolation limits for process equipment. These limits, coupled with the characterizing variable for scale-up determine the size of a pilot plant, if required. Given an estimate of the ultimate plant size, the minimum pilot-plant size can be determined (other considerations not controlling) from the allowable scale-up ratios. Conversely the reliability of a design extrapolated from small-scale equipment can be gauged from these ratios.

In the design and operation of a pilot plant, care should be taken to permit accurate measurement and control of the most important design variable; however, it should not be forgotten that, depending upon the specific application, a number of items may be equally important in the final plant design.

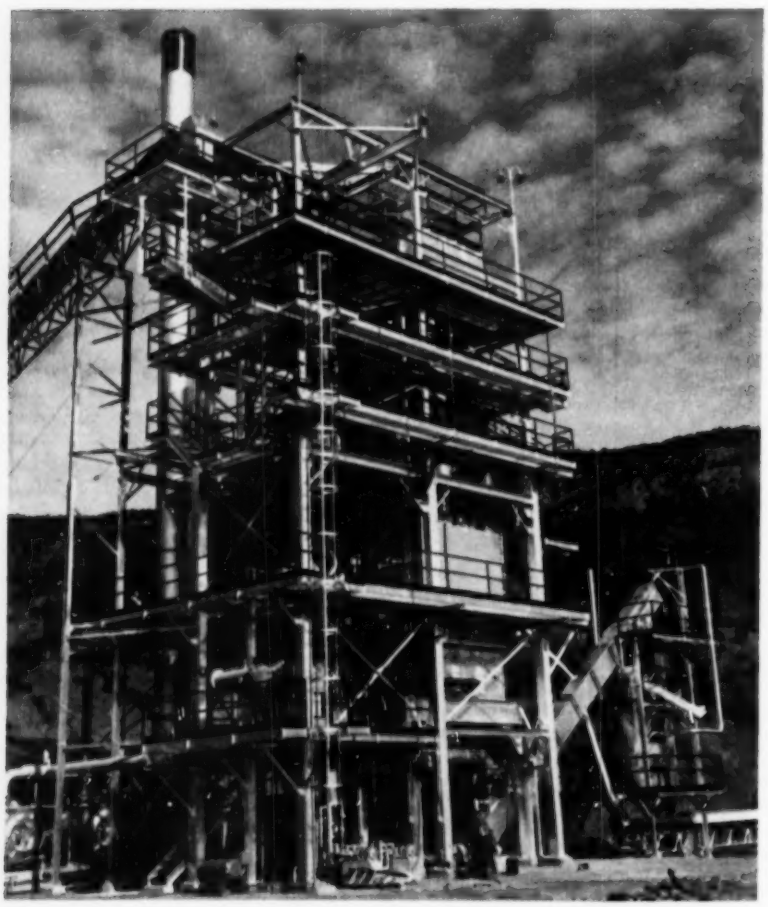
Finally, safety or overdesign factors applicable to the average case have been suggested to account for changes in operating performance with time. Additional safety factors, dictated by economic or market considerations, should be added to these when required.

Presented at A.I.Ch.E. Springfield meeting.

Oil from Shale

Russell J. Cameron and Boyd Guthrie Bureau of Mines, Rifle, Colo.

Although at the present time there is no commercial production of shale oil in the United States, considerable effort has been directed toward the development of an oil-shale-retorting process adapted to the type of oil shale, as well as to the economic conditions prevailing. Shale oil can be produced by simple pyrolysis, but the scale of production necessary, the relatively small yield of oil, and the location of the principal deposits in an area of limited water supply present sizable engineering problems. These conditions dictate that the successful American oil-shale process has high unit capacity, efficient energy utilization, and uses little or no water. This paper traces the development work which has led to the construction and operation of such an engineering plant.



Gas-combustion retorting process engineering plant.

Oil shales of the Green River formation, occurring in large continuous deposits in Colorado, Utah, and Wyoming, represent a huge potential of liquid hydrocarbon fuels. Conservative estimates (*1*) indicate recoverable reserves of more than 80 billion barrels of crude shale oil from oil shale yielding an average of 30 gal./ton. Fuel quantities of such magnitude have prompted activity by both government and industry toward developing low-cost methods for utilizing the oil shales from these reserves.

Background for Process Development

Although shale oil has been produced throughout the world for more than 100 years, there has been no substantial production in the United States because of an abundance of cheaper natural petroleum. Some processes were developed experimentally in the period immediately following World War I, but most operations were on a small scale and none were commercially successful. The foreign industries (*7*) in general have not fared well and have been kept alive through subsidy. Some oil-shale retorts operated commercially in Europe and elsewhere will process Green River oil shale, but the methods are too expensive to be applicable in this country. Other processes fail technically because of basic differences between the types of oil shale. At the inception of the Government's Synthetic Liquid Fuels program in 1944 (*24*), no retorting process was known that could produce shale oil in the quantity and at a cost considered feasible in the American economy.

Requirements for a Successful Oil-Shale Process

1. United States petroleum demands are measured in fantastically large figures—during 1944, 5 million barrels/day, in 1953 almost 8 million, and in 1975 an estimated 14 million (*25*). Shale-oil production, to be significant as a source of liquid fuels, also must be on a large scale, perhaps 50,000 bbl./day for a single plant. To avoid excessive multiplicity with attendant high capital and operating costs, individual processing units must necessarily handle large tonnages of shale; therefore, a require-

ment for the successful retort is a high throughput and operability in units of large individual capacity.

2. When kerogen, the organic matter in oil shale, is pyrolyzed, three products are formed—oil, gas, and a carbonaceous residue. Almost 30% of the heating value of the shale is contained in the gas and the carbonaceous residue. In order not to use a part of the shale oil as fuel, thereby decreasing the already small (10-12 wt. %) yield of oil, it is axiomatic that a successful oil-shale process derive its energy from the gas, the carbonaceous residue, or a combination of the two.

3. The U.S. principal oil-shale deposits are in a semiarid region, of which the only water source is the Colorado River. Irrigation is practised extensively, and the total water supply during periods of low river flow is allocated for this and other purposes. Although water could be made available for use in oil-shale processing by storage during periods of high stream flow, such a procedure would be most expensive; therefore, a third axiom is the use of little or no process water in shale-oil production.

Initial Investigations

A study of the existing practice (*8*) revealed hundreds of different oil-shale-retorting schemes. Despite the apparent multiplicity of processes, there is a common denominator—the application of heat. Essentially all retorts fit into the following broad system of classification, based on the method of applying heat to the shale:

I Indirect heating through the wall of the retorting vessel.

II Direct heating by hot gas from combustion within the retorting vessel.

III Heat transfer from an externally heated carrier fluid.

IV Heat transfer from hot, recycled retorted shale.

V Electric heating methods.

Class I retorts generally suffer from low heat-transfer rates and have corresponding low throughputs, the vessel size is limited, and thermal efficiencies are low. Class V processes should be given little consideration because of the high cost of electricity. Classes II, III, and IV, all of which use some measure of direct heat transfer, seemed to exhibit the greatest promise of fulfilling the requirements for a successful retorting process.

The first method to be investigated experimentally at Rifle was a Class II retort represented by the N.T.U.† process (*3, 9, 12*). This process, although not a new development, was operated early in the program to study this basic method of retorting and to obtain a supply of shale oil for refining research.

† Nevada-Texas-Utah type retort.

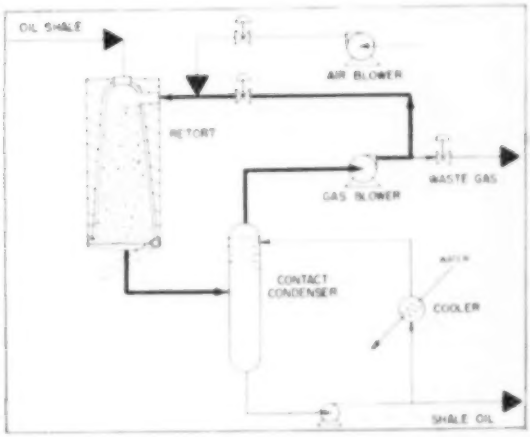


Fig. 1. N.T.U. oil-shale retorting process.

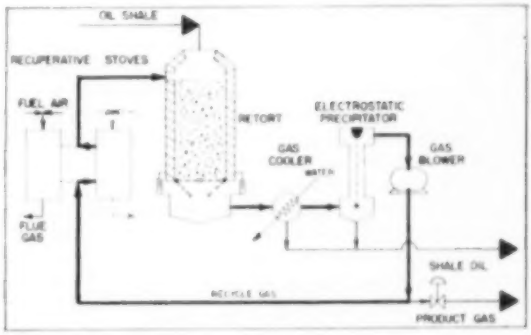


Fig. 2. Royster low-temperature carbonizer.

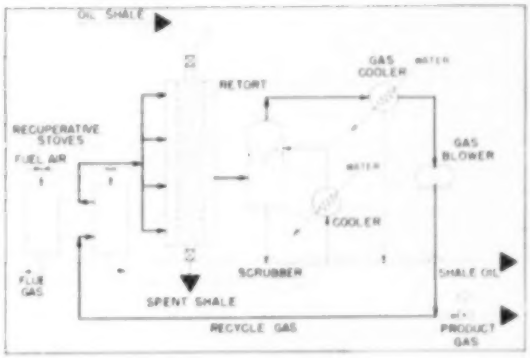


Fig. 3. Gas-flow oil-shale retorting process.

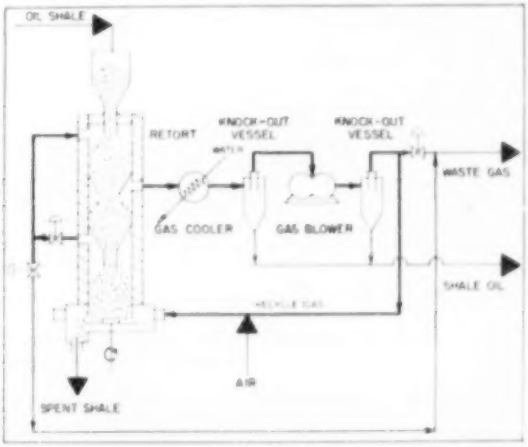
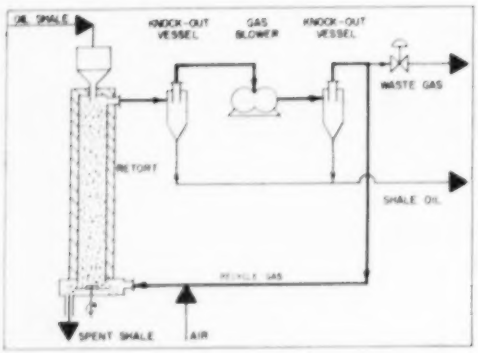
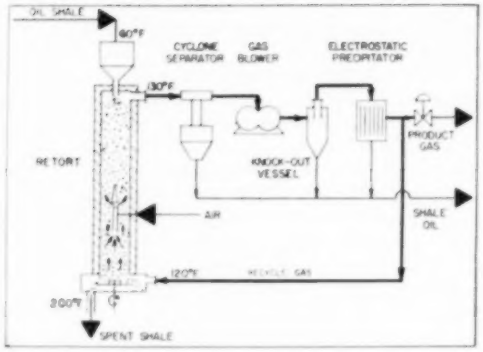


Fig. 4. Dual-flow oil-shale retorting process.



◀ Fig. 5. Countercurrent oil-shale retorting process.

Fig. 6. Gas-combustion oil-shale retorting process. ▶



The N.T.U. is a batch retort which uses as a heating medium the hot flue gas generated by burning organic residue in the spent shale. Figure 1 is a simplified flow diagram of the process. The retort is a brick-lined vessel with a hinged grate that can be opened to dump the spent shale. The product stream is cooled in a bubble tower by contact with a stream of recirculated product oil. Lean gas from the contact condenser may be recycled to the retort to be mixed with combustion air for temperature control. After the vessel has been filled with crushed shale, a fire lighted on top of the shale bed is made to progress downward by a downdraft of air or a mixture of air and recycle gas. The hot, inert flue gas from combustion of the spent shale heats the shale immediately below the combustion zone, decomposes the kerogen, and carries the products to the condensing system. As soon as the shale near the grate is heated to retorting temperature, the batch is dumped and the procedure repeated.

Performance of the N.T.U. process had both good and bad features. Batchwise operation is obviously undesirable. Retorting rates were low—80 to 100 lb./(hr.)(sq.ft.) of cross-sectional bed area—with the time required for recharging further reducing its capacity. Oil yields are not particularly good and are lowest at the higher throughputs. On the other hand, the process is self-sufficient heatwise—heat generation and most of the heat transfer take place in the retorting vessel, and the equipment is simple and trouble-free. Table 1 shows typical operating data from a 40-ton unit.

Certain undesirable features of the N.T.U.-type operation were believed to be caused by combustion in the shale bed. Some loss of the product from burning was possible. Fusion of the ash to a semifluid mass by the high temperatures could cause channeling of the gas, resulting in areas of unretorted shale. Furthermore, dilution of the shale gas with products of combustion lessened the value of the gas or eliminated it as a source of energy. It was believed that these deficiencies could be overcome by the use of an externally heated gas as the heat-carrying medium, i.e., Class III retorting.

A small Royster low-temperature coal carbonizer (*5, 10, 26*) was made available by the Tennessee Valley Authority for a preliminary test at Wilson Dam, Ala. When these tests showed promise, a similar unit of 1,400-lb. capacity (2.5-ft. I.D.) was obtained for further study at Rifle. The Royster carbonizer, illustrated in Figure 2, is a refractory-lined vessel operated batchwise, hot gas being supplied by recuperative pebble stoves. In operation on oil shale, product gas is recirculated as the heating medium with no combustion in the retort. Product gas passes through a water-cooled condenser and an electrostatic precipitator for oil recovery before being recycled to the stoves. The recovery equipment is not a critical feature of the process and merely happened to be supplied with the pilot-plant equipment.

Typical results from the Royster operations are shown in Table 1. Excellent yields were obtained, many runs approximating the Fischer assay of the shale. Mass shale rates far exceeded those found for the N.T.U., ranging as high as 250 lb./(hr.)(sq.ft.). Product-gas heating values were of the order of 300 B.t.u./cu.ft.

A continuous retort was devised to obtain the high yields and throughput rates possible with the Royster-type process, and a 12-ton/day pilot plant for what was called the Gas-Flow process (*6, 10, 13, 15, 18, 22*), illustrated in Figure 3, was built. Crushed shale flows by gravity through the retort as a bed of freely moving particles. The bed is contained on two sides by metal louvers through which is maintained a cross flow of hot gases to heat the shale to retorting temperature. The gas stream from the vessel is cooled in a scrubbing tower by direct contact with recirculated product oil. Recycled product gas is heated in recuperative stoves and returned to the retort.

Good operating results were obtained in the pilot plant, shale rates of twice or three times the throughput of the con-

Table 1.—Comparison of Operating Conditions and Product Yields for Different Experimental Retorts

Process	N.T.U.	Royster	Gas-Flow	Counter-current	Gas-Combustion
Capacity:					
Tons/batch	40	0.7	Continuous	Continuous	Continuous
Hours required/batch	10-14	2-3	.....	....	....
Tons/day	.....	.....	12	5	6
Shale rate, lb./(hr.)(sq.ft.)	80-100	150-250	1,000	190	233
Product Oil:					
Recovery, vol. % of Fischer assay	80-90	100	90-100	90	95
Gravity, ° A.P.I.	20.3	19.8	17.2	20.3	20.1
Viscosity, S.U.S. @ 130° F.	48.4	167	242	114	127
Viscosity, S.U.S. @ 210° F.	4.5	72	60	46	52
Pour point, ° F.	90	90	80	90	90
Gas produced:					
M std. cu.ft./ton shale	14-17	1.6-1.8	0.8-1.2	12	5.8
B.t.u./cu.ft.	60	300	300	45	90

Table 2.—Effect of Product Outlet Temperature on Oil Yields in the Dual-Flow Retorting Process

Product outlet temperature, ° F.	370	271	203
Oil yield, vol. % of Fischer assay	71	77	93
Shale rate, lb./(hr.)(sq.ft.)	77	99	131

Table 3.—Operating Conditions and Summary of Yields from Gas-Combustion Pilot Plant : 10-day Retorting Run

Run history:	
Date, 1952	1/17-1/27
Length of run, days	10
Shale feed:	
Fischer assay, gal./ton	29.0
Total feed, tons	61
Feed rate, tons/day	6.1
Throughput rate, lb. shale/(hr.)(sq.ft.) of bed area	233
Resulting conditions:	
Air required, std. cu.ft./ton of shale	3,760
Recycle gas required, std. cu.ft./ton of shale	16,620
Superficial linear gas velocity, ft./sec.	0.73
Temperatures, ° F.:	
Products (leaving retort)	123
Retorted shale (leaving retort)	185
Oil-yield summary (water-free oil):	
Liquid oil collected, gal./ton	27.3
Vol. %, Fischer assay	94.1
Wt. %, Fischer assay	96.4
Product-gas yield:	
Volume of gas, std. cu.ft./ton	5,810

Table 4.—Properties of Shale Feed for Gas-Combustion Pilot Plant: 10-day Retorting Run

Fischer assay oil content, gal./ton		29.0
Mineral carbon dioxide, wt. %		17.0
Screen analysis, in., wt. %		
−1.50 + 1.05	"	6.1
−1.05 + .742	"	37.5
−.742 + .525	"	27.6
−.525 + .371	"	21.0
−.371 + . 263	"	6.1
−.263 + .185	"	1.1
−.185 + .131	"	.2
Pan + loss	"	.4

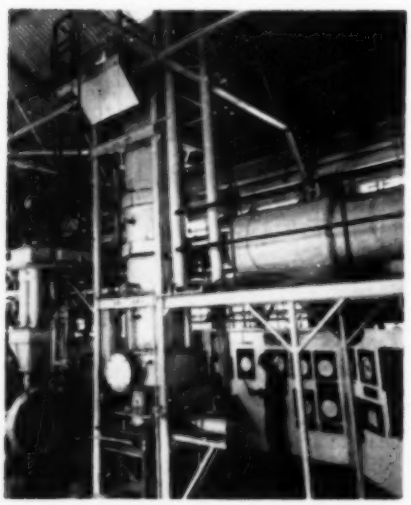
ventional N.T.U. (or other) retort being possible with the cross-flow system. Typical operational data are shown in Table 1. In most respects performance duplicated or exceeded Royster results. However, despite its advantages of high throughput and high yields, the inherently high investment cost for a process requiring the external heating and cooling of gases made it economically unattractive.

Development of Gas-Combustion Process

With the previous experimentation as a background, it was decided to return to Class II heating methods and investigate gravity-flow processes using hot flue gas as the heating medium. A small, 20-in.-diam. pilot plant was constructed with provision for a variety of process arrangements. External heat exchange would be reduced to a minimum and heat economy obtained by countercurrent gas and shale flow wherever possible. Since retorting rate obviously is an important consideration, reasons for its limitation in an internally fired retort, such as the N.T.U. were examined. The answer indicated the burning rate of the spent shale. The carbonaceous residue, which is the fuel in the spent shale, amounts to only 2 or 3% by weight and is distributed throughout the particle. After the surface has been burned, oxygen must diffuse into the particle against the outward flow of products of combustion as well as carbon dioxide from decomposition of mineral carbonate. There is little doubt that the burning process in this case is slower than if fuel were easily available. The solution of the problem seemed to be to relegate spent shale to a secondary position as a source of energy, using recycled product gas, which should have a faster burning rate, as the principal fuel.

The first arrangement tested, dubbed the Dual-Flow (*4*), is shown by Figure 4. Crushed shale moves down as a slowly moving bed first to a preheating, then to a retorting, and finally to a combustion section before being discharged from the retort. The gas offtake at the center of the retort was designed to keep the gas stream at a high enough temperature to prevent condensation of oil in the retort. Successive experiments to reduce the offgas temperature to a minimum (the results of which are given in Table 2) surprisingly showed no condensation of the oil in the retort at temperatures far below the dew point of the oil. The explanation for this phenomenon is the formatoin of a stable shale-oil mist in the gas stream rather than condensation on the shale particles.

Results from the Dual-Flow experiments indicated a change in operation to the Countercurrent process (see Figure 5). Air and recycle gas are introduced at the bottom of the retort. Recycle gas burns in a zone above the grate, the hot flue gas retorting the shale and being cooled in successive zones higher in the vessel. This operation was disappointing in that the air-recycle-gas mixture reached the kindling temperature very near the discharge grate, leaving insufficient bed height for the spent shale to exchange heat with the gas stream. The result was high spent-shale temperature, lowered thermal efficiency, and a higher air requirement,



◄ Fig. 7. Gas-combustion pilot plant retort.

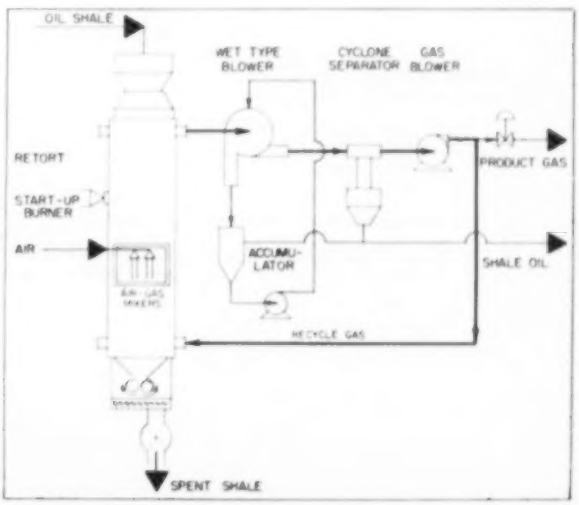


Fig. 9. Engineering plant gas-combustion retorting process. ►

Table 5.—Properties of Retort Products from Gas-Combustion Pilot Plant : 10-day Retorting Run

Properties of crude oil:	
Gravity, ° A.P.I. @ 60° F.	20.1
Specific gravity, @ 60° F.	.933
Viscosity, sec.:	
S.U.S. @ 130° F.	127
S.U.S. @ 210° F.	51.7
Ramsbottom carbon residue, wt. %	2.40
Water, vol. %	6.6
Nitrogen, wt. %	2.16
Sulfur, "	.66
Ash, "	.056
Vacuum distillation (40 mm. corrected to 760 mm.), %	
I.B.P. @ ° F.	360
2 @ "	405
5 @ "	448
10 @ "	505
20 @ "	596
30 @ "	680
40 @ "	758
50 @ "	837
59.2 @ "	900
Residuum, vol. %	40.6
Properties of product gas:	
Gross heating value, B.t.u./std. cu.ft	90
Water vapor content, vol. %	12.6
Orsat analysis—(dry basis), volume %:	
CO_2	27.0
Illuminants	1.4
O_2	.2
CO	4.8
H_2	5.0
CH_4	2.5
C_2H_6	.6
N_2	58.5
Properties of retorted shale:	
Fischer assay oil content, gal./ton	.4
Mineral carbon dioxide, wt. %	16.1

Table 6.—Gas-Combustion Pilot Plant Heat Balance on Retort Vessel : 10-day Retorting Run

Basis: 2,000 lb. of raw shale as charged.
Datum: 60° F. water as liquid.

	Wt. lb.	Temp. ° F.	Heat B.t.u.
Heat in:			
Shale	2,000	26	—17,000
Recycle gas	1,280	118	124,000
Air	289	82	1,500
Gross heat of combustion	.....	...	378,000
Total	.....	...	486,500
Heat out:			
Retorted shale	1,544	175	37,000
Product oil	212	123	5,000
Gas	1,725	123	194,000
Carbonate decomposition	.....	...	104,000
Radiation and convection losses	.....	...	50,000
Subtotal	.....	...	390,000
Unaccounted for	.....	...	96,500
Total	.....	...	486,500

with greater product-gas dilution by products of combustion (See Table 1 for the typical operating results for the Countercurrent process).

Fixing the combustion zone higher in the retort to provide sufficient heat exchange was accomplished by introducing the air and recycle gas separately—the recycle gas to the bottom of the retort to cool the spent shale and the air at a point high enough in the vessel to allow enough bed height for spent-shale cooling. Though this arrangement had the desired effect of causing the spent shale and recycle gas to exchange heat, injection of air directly into the vessel caused local heating to temperatures in excess of the fusion point of the shale, resulting in clinkers that made the process inoperable. Successful operation was achieved by providing an air-gas mixer in order that the air could be diluted with recycle gas before entering the shale bed. The means was simply providing a void to allow some recycle gas to disengage from the shale bed and injecting the air into this space for mixing. This system, named the Gas-Combustion process (*14, 17, 21*), is shown schematically in Figure 6. Figure 7 illustrates the 6-ton/day Gas-Combustion pilot plant, which evolved from the experimental work on the Dual-Flow and Countercurrent processes.

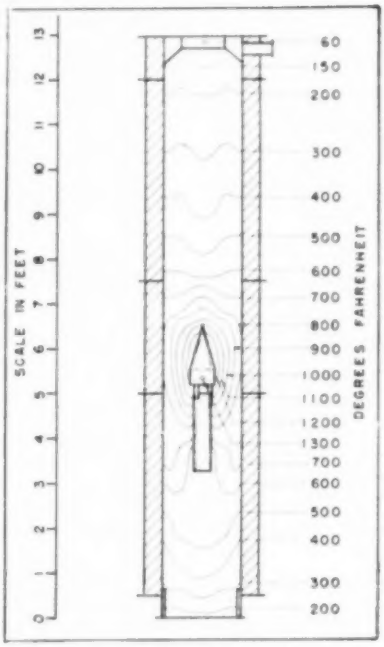


Fig. 8. Gas-combustion pilot plant retort isothermal cross section.

In the experimental work most of the variables thought to affect the operation were investigated—air and recycle-gas rates, shale rate, particle size, and shale grade. Several mechanical arrangements for mixing air and recycle gas also were tested, but none yet have proved superior to the original design. One of the important variables (bed height above the combustion zone) was not studied because of equipment limitations, nor was particle size as thoroughly investigated as would have been desirable because of the small diameter of the vessel.

Other operating variables with resultant problems were studied as follows:

Air rate was determined to influence mainly the completeness of retorting and the operability of the retort. Insufficient air leaves oil values in the spent shale; excessive air results in high combustion zone temperatures and clinker formation, as well as a thermal unbalance and lowered oil yield. *Recycle-gas rate* must be sufficient to cool the spent shale. Moreover, the total gas rate must be such that the proper cooling rate for stable mist formation is obtained in the heat-exchange zone at the top of the retort. Pilot-plant operations have

shown the value for total gas to be rather critical. Increases in *shale rate* above about 250 lb./(hr.)(sq.ft.) have adversely affected operability (clinker formation, erratic shale, and gas flow) of the pilot plant and to some extent have shown lower oil yields. The poor operability, and not the higher shale rates, probably is responsible for lowered yields. At the higher rates there is a greater heat release in the combustion zone and more tendency for localized overheating. *Shale grade* was not thoroughly investigated, but shale with assay values much above 30 gal./ton was found to coke and clinker more easily than those below this value.

Representative operating conditions and a summary of yields of the 6-ton/day pilot plant are listed in Table 3. These particular figures are the average results of a 10-day performance test conducted in January, 1952. Table 4 shows the shale-feed properties during the test, and properties of the retort products, oil, gas, and spent shale are given in Table 5.

The temperatures at various points in the system are of considerable significance. Raw shale enters at 60° F. and the spent shale leaves at about 200° F. In spite of the fact that the spent shale is about 80% the weight of the raw shale entering, the heat loss from this source is small. Gases entering the retort (air and recycle gas) have a weighted average temperature of about 120° F., and product gas carrying the condensed oil leaves at about 130° F. The heat loss by this source also is small. The principal heat requirements are endothermic reactions within the retort, the decomposition of magnesium and calcium carbonates being the largest accountable heat requirement. An approximate heat balance for the 20-in.-diam. pilot plant is shown in Table 6. In Figure 8 one can see a cross section of the 6-ton/day Gas-Combustion pilot plant, showing isothermal lines through the shale bed. It may be noted that the highest recorded temperature is 1,300° F. occurring immediately above the top of the air-gas mixer.

Perhaps the most important feature of the Gas-Combustion process, one that makes its successful operation possible, is control of conditions to form a stable shale-oil mist that will remove liquid oil from the top of the retort at a low temperature. In the retorting zone the oil is liberated as a vapor. As this vapor moves upward through the descending cold shale, it is cooled to a temperature below the dew point of the oil. If the proper conditions of heat transfer are established, the gas can become supersaturated with respect to the oil, which condenses as minute droplets directly in the gas stream rather than as a film on the shale. The oil mist then will be carried out of the retort by the cold gas without any significant loss by impingement on the shale particles. Relatively common devices, such as cyclones, electrostatic precipitators, or even high-speed gas blowers, will efficiently remove the oil from the gas stream.

Oil from the Gas-Combustion process (Table 5) has characteristics similar to those of most other Green River shale oils. It falls into the classification of a heavy oil (about 20° A.P.I.) and has a pour point of about 90° F. Sulfur content is moderate (0.7 wt. %), but nitrogen, present as organic nitrogen compounds, is very high (more than 2% by weight). Low-boiling constituents are almost absent or evidenced by the high initial boiling point. A further characteristic of shale oil of this type is a high percentage of unsaturated compounds.

The combustible gas produced in the process is the gas formed from the pyrolysis of kerogen diluted by the products of combustion. When preheated the 90-B.t.u./cu.ft. gas is a satisfactory fuel—in the range of blast-furnace gas—and represents about 10% of the heating value of the raw shale.

The Engineering Plant

When it became evident that a superior oil-shale processing operation had been achieved by the small pilot plant, an engineering model of the process was designed and constructed (*2, 19, 23*). Cross-sectional area was 60 sq.ft. compared with 2.2 sq.ft. for the small unit. Shale throughput for the larger plant, at conditions found most operable in the pilot plant, is 150 tons/day; however, all equipment has been designed for twice this rate.

Since it was desired to study variables not possible in the smaller unit—shale particle size, bed height, and a new factor, spacing and geometry of the air-gas mixers—considerable flexibility was built into the plant. As a concession to ease of air-gas mixer removal and adjustment, the vessel is rectangular in cross section. A schematic flow diagram of the plant is given as Figure 9, and the photograph on page 336 illustrates the completed installation.

No operational data are shown for the engineering plant since at the writing of this paper only shakedown runs have been made and accurate results are not available.

Acknowledgments

The authors gratefully acknowledge the help of members of the Bureau of Mines process-development staff at Rifle, all of whom assisted in the development of the retorting processes. Special acknowledgments are due the following Bureau employees for taking the lead in developing the retorting process described: J. D. Lankford, J. R. Ruark, J. G. Tripp, M. W. Putman, J. B. Jones, A. A. Reeves, and A. Matzick. Specific acknowledgment is made to R. G. Beverly for his helpful suggestions in preparation of the manuscript.

Literature Cited

1. Belser, Carl, *Green River Oil-Shale Reserves of Northwestern Colorado, U.S. Bur. Mines Rept. Invest.* 4769, 1-13 (1951).
2. Brakel, L. H., *Trans. Am. Inst. Mech. Engrs.*, **75**, No. 3, 441-451 (1953).
3. Cottell, R. A., Boyd Guthrie, and L. W. Schramm, Retorting Colorado Oil Shale, *Oil Shale and Cannel Coal*, **2**, 353-358 (1951).
4. *Ibid.*, 359-360.
5. *Ibid.*, 361-362.
6. *Ibid.*, 362-370.
7. Guthrie, Boyd and Simon Klosky, *The Oil-Shale Industries of Europe, Bur. Mines Rept. Invest.* 4776, 1-73 (1951).
8. Klosky, Simon, An Index of Oil-Shale Patents, *Bur. Mines Bull.* 468, 1-650 (1949).
9. Oil from Oil Shale, 1948 Annual Report of Secretary of Interior on Synthetic Liquid Fuels, Part II, *Bur. Mines Dept. Invest.* 4457, 11-17 (1949).
10. *Ibid.*, 25-26.
12. Oil from Oil Shale, 1949 Annual Report of Secretary of Interior on Synthetic Liquid Fuels, Part II, *Bur. Mines Rept. Invest.* 4652, 16-17 (1950).
13. *Ibid.*, 17-22.
14. Oil from Oil Shale, 1950 Annual Report of the Secretary of the Interior on Synthetic Liquid Fuels, Part II, *Bur. Mines Rept. Invest.* 4771, 20-27 (1951).
15. *Ibid.*, 27-31.
16. *Ibid.*, 46-53.
17. Oil from Oil Shale, 1951 Annual Report of Secretary of Interior on Synthetic Liquid Fuels, Part II, *Bur. Mines Rept. Invest.* 4866, 16-22 (1952).
18. *Ibid.*, 23.
19. *Ibid.*, 24-26.
24. *Ibid.*, 43-56.
21. Oil from Oil Shale, 1951 Annual Report of Secretary of Interior on Synthetic Liquid Fuels, Part II, *Bur. Mines Rept. Invest.* 4943, 8-12 ((1953).
22. *Ibid.*, 13.
23. *Ibid.*, 15-17.
24. Public Law 290, 78th Congress, as amended by Public Law 443, 80th Congress and Public Law 812, 81st Congress.
25. Resources for Freedom, Report to President by Materials Policy Commission, **2**, 4 (1952).
26. Wells, W. E., and J. R. Ruark, *Pilot-Plant Batch Retorting of Colorado Oil Shale, Bur. Mines Rept. Invest.* 4874, 1-19 (1952).

Presented at 45th Annual Meeting of the A.I.Ch.E., St. Louis, Mo.

Economics of Coal Carbonization

by the Low-Temperature Process

R. G. Minet, H. B. Smith, Jr., and C. A. Trilling United Engineers & Constructors Inc., Philadelphia, Pennsylvania

For more than sixty years coal technologists have experimented with processes which would allow the economic recovery of valuable oils and tars from coal without the huge initial investment requirement of conventional by-product coke ovens. One of the most popular approaches has been the low-temperature carbonization technique involving the destructive distillation of coal at temperatures of 900 to 1,000° F. The history of low-temperature carbonization is a story of great enterprise, high enthusiasm, and frequent failure (*7*).

At present the only commercially successful low-temperature carbonization plant in this country is operated by the Pittsburgh Consolidation Coal Co. (*10*), which uses the Disco process to convert 1,000 tons a day of slack coal into premium domestic fuel in the form of coke balls. Though this process is of significance in that it upgrades low-value coal material and provides a basis for a low-temperature tar-market structure, it does not appear readily adaptable to the high through-put, low first-cost requirements of modern industry.

The present state of the art was reviewed by Zinn in 1952 (*20*). Last year the Aluminum Company of America and the Texas Power & Light Co. announced a joint enterprise for the installation of a lignite drying and low-temperature carbonization plant at Sandow, Tex. (*21*). Construction is underway on the drying step to handle 400 tons/hr. of Texas lignite. Eventually, carbonization facilities will be added and carbonized char will be burned under the boilers in place of dried lignite to supply power for the aluminum reduction plant. Present plans call for the use of pitch and coke derived from low-temperature tar as electrode materials in the aluminum reduction process. Other chemicals recovered from the carbonization step will provide a source of by-product income which is expected to reduce the over-all cost of power to less than 3 mills/kw.hr. The carbonization process to be used at Sandow is an up-flow fluidized bed scheme developed by V. F. Parry at the United States Bureau of Mines, Denver Station, for use with lignite or other noncoking coals (*12*).

Recently a process developed by the Pittsburgh Consolidation Coal Co. for carbonizing coking bituminous coals was announced (*24*). The pilot plant, designed to handle about 50 tons/day, has been operating satisfactorily, it is reported, since February, 1953. A description of this process has not yet been published.

Design of Plant

As part of a program looking toward the use of modern techniques of chemical engineering in coal utilization, United Engineers undertook an engineering study of low-temperature carbonization processes. Based on available information, a carbonization system for bituminous coal was worked out which appears to offer reasonable promise of success. It is a modification of processes previously described in the literature (*9, 15, 17, 20, 22*).

Description of Process

Figure 1 is a simplified flow diagram of the low-temperature carbonization process. Coal, delivered into the carbonization plant from conventional coal-handling and field-storage facilities, is reduced to 100% through ⅛-in. mesh by a hammer mill and fed into a fluidized bed of hot coal which is heated to 400° F. by a stream of hot combustion gas. By controlling the composition of the heating gas, a small amount of oxygen is combined with the coal to diminish its coking tendency and thus assist in preventing agglomeration in later processing steps.

Coal leaves the preoxidizer and passes down a standpipe through a slide valve into a transport line where high velocity recycled carboniza-

tion gas carries it upward into the carbonizer. As the mixture of coal and carbonization gas passes under the heat generator, a controlled quantity of char heated to 1,200° F. is added. A recycle of approximately three parts of heated char to one part of coal is required for normal operation of the carbonizer at 900° F. Besides providing carbonization heat, this recycle is expected to eliminate agglomeration difficulties.

Char recycled from the carbonizer flows by gravity into the heat generator. The fluidized char is blown with preheated air to maintain the temperature at 1,200° F. by the combustion of approximately 3% of the char produced. Combustion gas from the heat generator passes out through cyclone separators and is further heated to approximately 1,800° F. in a direct-fired heater before entering the preoxidizer. Product char from the carbonizer is passed through a waste-heat boiler, cooled to 400 or 500° F. and pneumatically conveyed to storage hoppers by oxygen-free combustion gases.

Volatile oils and gas distilled from the coal leave the carbonizer through multistage cyclones and pass to the tar-recovery system. The method used for recovering liquids from the carbonization gas is essentially similar to fractionator installations in fluid catalytic-cracking units.

As shown on the diagram, the carbonizer effluent enters the fractionator and passes up through several disc and donut sections where it is rapidly desuperheated by contact with recirculated pitch. A few trays up the tower, a creosote fraction is withdrawn as a side stream from the bubble-cap-equipped section. Still further up, a stream is withdrawn which is used as an absorption oil and also forms part of the acid oil product. The light oil product and the liquor formed during carbonization are condensed and collected in the fractionator accumulator. The uncondensed gas is compressed and passes through the gas absorber for recovery of light oil. Part of this gas is recycled to the carbonizer to provide a fluidizing medium. The net gas make is desulfurized and delivered to fuel gas mains.

Light oils collected in the fractionator accumulator are separated into forerunnings, light oil and acid oil by conventional distillation equipment. The liquor collected is treated for the recovery of water soluble phenols in a simple solvent extraction process.

Estimate of Investment

The engineering-estimate summary (Table 1) was prepared for a low-temperature carbonization plant having sufficient capacity to process 8,520 tons/day of Ohio bituminous coal. Included in the estimate were the carbonization plant, the fractionation and product recovery plant, etc., and all auxiliary facilities required for the operation of the complete plant. It was assumed that the plant was located in an area requiring extensive piling for foundation supports.

Process equipment in contact with tar acid streams was designed for maximum corrosion resistance. For example, Monel clad shells and Monel bubble trays were specified for distillation towers. Monel and type 316 stainless steel were specified for tubular heat exchangers and interconnecting pipe. Selection of materials of construction was based on the experience of the Coalite Corp. in England as reported by Bristow (*2*) which provided a conservative basis for estimating material costs.

Labor rates and material costs are based on May, 1953, figures for operations conducted at a construction site in the Great Lakes region.

VARIATION OF INVESTMENT WITH CAPACITY

On the basis of data shown in Table 1 and other estimates prepared for smaller size plants, Figure 2 was plotted to show the approximate variation of plant cost with coal-charging capacity. Handling high-moisture-or high-ash-content coals would result in variations from the line shown in that figure. It is assumed that the range of composition for which this curve will hold is approximately 15% total moisture and 15% total ash content. Other characteristics of coals, such as coking tendency, grindability, sulfur content, etc. will influence the size and cost of the plant.

Products of Coal Carbonization

The Ohio bituminous coal, used as the basis of design (Table 2), is a typical commercial coal, having a moderately high-ash content. The oxygen content of 7.3% indicates probable coking characteristics. Of the 2.9% sulfur present, approximately half will appear in the liquid and gas product. Yields of char, gas, tar, and liquor obtained from the carbonization of this coal at 900° F., were estimated from Bureau of Mines data. (*4, 5, 6*). The estimated yields (see Table 3) are based on distillation assays with use of Bureau of Mines-American Gas Association retort. Since substantially higher yields of liquid products have been reported for the fluidized carbonization of coal (*17*), the estimated liquid yields presented here are probably quite conservative, amounting to slightly more than 23 gal./ton.

The calculated daily yields of products from the carbonization process (Figure 1) are given in Table 4. Adjustments have been made for quantities of gas and char consumed to supply process heat requirements. Approximately 3% of the char and ⅓ of the gas product are burned in the process. Phenols recovered from the waste-liquor treating operation are included in the acid oil product.

Evaluation of Products

The bituminous coal considered in this evaluation costs 25.8 cents/1,000,000 B.t.u. delivered to the plant site in the Great Lakes region. Char and fuel gas were assigned the same value of 25.8 cents/1,000,000 B.t.u. for payout calculations.

Since the liquid products of low-temperature carbonization processes have not been marketed in this country in any substantial quantities, the following technique was used to estimate a price for each stream:

1. Only those constituents present in the low-temperature tar which are reasonably similar to chemicals on the present market were assigned values other than fuel value.
2. To allow for doubt on the equivalence of the low-temperature tar product with the product currently on the market, a differential of 20 to 40% was applied to the selling price.
3. The cost of separating the individual constituents was estimated on the basis of known operations such as distillation, solvent extraction, etc., using processes common to coal-tar refining, or processes reported in the literature.
4. On the basis of the foregoing, a selling price was estimated for the crude product streams delivered by the plant; this price includes an additional differential for marketing expense.

The use of this method of price estimation may be illustrated as follows:

Light oil is the smallest liquid product stream. Analysis shows it to be composed of approximately 50% aromatics such as benzene, toluene, and xylene and 50% of paraffins and cycloparaffins. Currently there is a strong demand for the aromatics, but paraffins are somewhat less valuable. In order to establish a price for this stream it was assumed that the aromatics could be separated by distillation and solvent extraction. Since the aromatics sell for approximately 30 to 40 cents/gal. (*23*) and the fuel value of the paraffin constituents is of the order of 10 cents/gal., the value of the light oil stream is approximately 22 to 24 cents/gal. Processing, including usual charges, should cost in the neighborhood of 2 to 4 cents/gal. If a mark-down of 20% is included to make the stream attractive commercially, a selling price of 16 cents/gal. is indicated for the light oil.

The product stream most similar to commercially available and currently marketed coal-tar products is creosote oil. Low-temperature creosote has a lower gravity and a somewhat higher

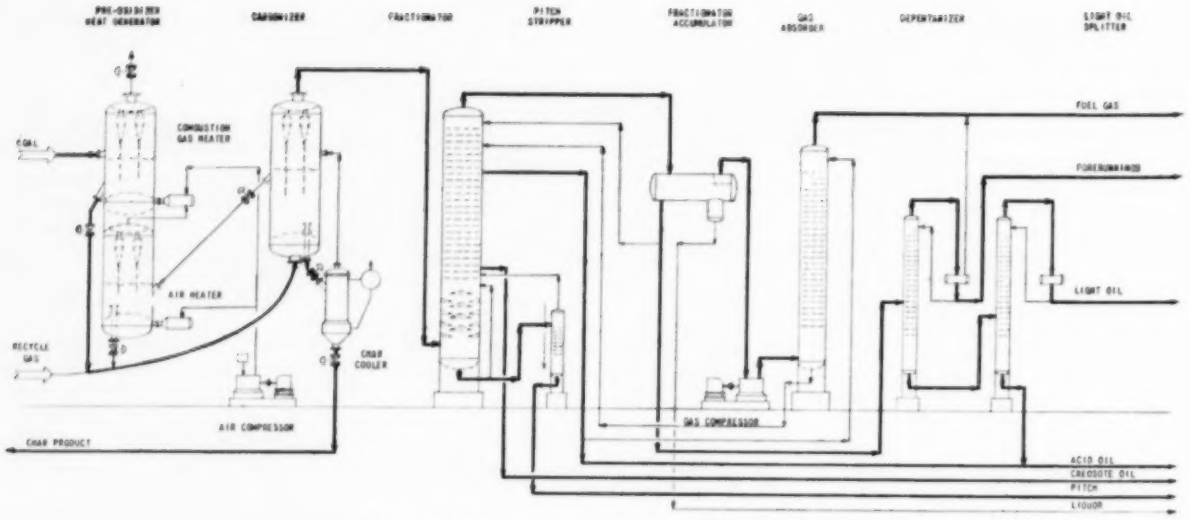


Fig. 1. Fluidized low-temperature carbonization process.

Table 1

INVESTMENT SUMMARY
8,520 TONS PER DAY PLANT

Item	Description	Amount
Buildings	Pump house and control room, compressor house and electrical building	$ 370,000
General plant facilities	Roads, area paving, grading, cooling water supply, railroad sidings, city water supply, storm and sanitary drainage, fuel oil line, electrical substation, yard lighting, signals and alarms	376,000
Carbonization plant	Solids-handling equipment, coal-storage facilities, process vessels, cyclone separators, direct-fired heaters, waste-heat boiler, compressors, condenser, pumps, piping, char and fuel gas lines to power station, insulation, foundations and supports, instruments and electrical work	4,257,000
Distillation plant	Process vessels, heat exchangers, pumps, compressors, piping, insulation, foundations and supports, instruments and electrical work	4,445,000
Sulfur recovery plant	Towers, converters, sulfur pit, heat exchangers, pumps, heaters, compressors, piping, insulation, foundations and supports, instruments, control house and electrical work	1,110,000
Phenolic liquor treating plant	Process vessels, heat exchangers, pumps, piping, insulation, foundations and supports, instruments and electrical work	297,000
Auxiliary steam generation	Boiler and auxiliaries, piping, insulation, foundations, instruments and electrical work	369,000
Liquid product storage and shipping facilities	Storage tanks, pumps, loading spouts and foamite system	198,000
Emergency and safety facilities	Flare, blowdown drum and pumpout cooler	78,000
Total estimate of cost		$11,500,000

Note.

Each of the above figures includes allowance for supervision, temporary facilities, tools and equipment, insurance and taxes, engineering, compensation and a 10 per cent contingency. Not included are char storage facilities, fencing, incoming power supply to substation, water treating facilities, auxiliary fuel gas supply, fire protection loop, legal fees or royalties, cost of permits, fire insurance during construction and interest on funds during construction.

acid content than the normal product (*23*). A selling price of 17 cents/gal. has been assumed for low-temperature creosote, allowing a margin of some 20% below the current selling price (*23*), to overcome sales resistance to a new product.

A good part of the revenue for this process should come from the sale of acid oil. About 50% of this stream is composed of tar acids such as phenol, cresol, xylenol and heavier compounds in the boiling range of 230 to 270° C. Tar bases, mainly homologues of pyridine, quinoline and aniline make up another 6%. The remaining material consists of solvent naphthas boiling between 170 and 200° C. Evaluating each of the constituent streams at its estimated market price (*23*), indicates an over-all value of 35 to 40 cents/gal. for the acid oil. If a processing cost of 5 to 6 cents/gal. is allowed and a discount of 33% included, a selling price of 22 cents/gal. is obtained.

Although the pitch produced by this process has many possible uses, for the purpose of this paper it has been assigned fuel value only. If it was converted into electrode pitch and electrode coke, it would be worth approximately $30.00 a ton. As a fuel it is worth 25.8 cents/1,000,000 B.t.u. or $8.25/ton.

Liquid sulfur recovered from the gas has been credited with its current market price of $20.00/ton. Water soluble phenols recovered from the liquor are included in the acid oil stream and are not given a separate evaluation.

Pay-out for Various Applications

Table 5 gives the annual income from the sale of products based on prices developed above. For a year's operation of 330 days, the sale of char, gas, and pitch as fuel, light oil at $0.16 a gallon, acid oil at $0.22 a gallon, creosote oil at $0.16 a gallon, and sulfur at $20.00 a ton will bring slightly more than $11,000,000.

The annual operating expenses for the plant are summarized in Table 6. Except for electricity, the utilities and services required are provided by facilities included as part of the carbonization plant.

The figures shown in Table 6 indicate an annual profit of $3,568,000, equivalent to a 31% return on the initial investment before federal income taxes as shown in Table 7. This is a 3.2 year pay-out for the complete plant, including auxiliary facilities. If the net profit of $3,568,000 is applied to reduce the value of char delivered from the carbonization plant, a substantial decrease is possible in the cost of fuel. For a power plant designed to use Ohio coal at 25.8 cents/1,000,000 B.t.u. operated in conjunction with this low-temperature carbonization plant, the net cost of fuel would be reduced to 18.4 cents/1,000,000 B.t.u., a saving of more than 28%. Further calculations indicate that the ultimate cost of fuel to the power plant can be reduced beyond 28% by the addition of process equipment to coke the pitch, and refine the acid and light oil streams. In operation, savings may accrue also from the reduced sulfur content of the char, its low-moisture content, and its smokeless burning characteristic.

Electrothermal Process

An attractive application for low-temperature carbonization appears to be in combination with electrothermal processes such as aluminum, calcium carbide or phosphorus production. In Table 8 the power and electrode-carbon requirements for several electrothermal processes are shown (*3, 13, 16, 19*). In addition to the lower power costs, there is promise that the pitch from the low-temperature carbonization of coal can be used as a raw material for the manufacture of electrode carbon. If credit can be given for this carbon at something near the $30.00/ton price currently quoted, the over-all economics of a combination plant would be very attractive.

Gasification

The announcement of plans for the installation of a new coal gasification process, developed by the Babcock & Wilcox Co. and the Bureau of Mines, at the Belle, W. Va., plant of the Du Pont Co., indicates that synthesis gas may be competitively generated from coal in certain cases (*8*). Recent papers have discussed the manufacture of pipe line and synthesis gas from coal to supply areas beyond the reach of natural gas (*1, 18*). If char is gasified, credit for the liquid products of low-temperature carbonization could bring a substantial decrease in the cost of the gas delivered to the pipe line. For example, on the basis of data presented by Alberts et al (*1*) and Newman (*11*), 900 B.t.u. gas produced from the Ohio

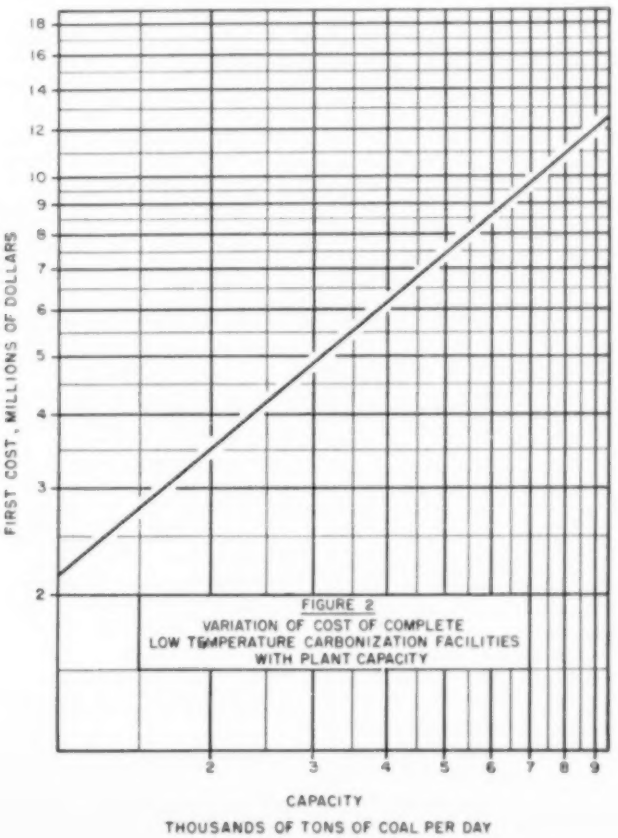


FIGURE 2
VARIATION OF COST OF COMPLETE LOW TEMPERATURE CARBONIZATION FACILITIES WITH PLANT CAPACITY

Table 2

ANALYSIS & PROPERTIES OF OHIO BITUMINOUS COAL

Proximate analysis of coal	Wt.%
Moisture	8.0
Volatile matter	34.2
Fixed carbon	46.9
Ash	10.9
	100.0
Ultimate analysis (moisture-free basis)	
Ash	11.9
Hydrogen	5.1
Carbon	71.4
Nitrogen	1.4
Oxygen	7.3
Sulfur	2.9
	100.0

Net heating value ..... 11,780 B.t.u./lb.

Table 3

ESTIMATED YIELDS FROM CARBONIZATION AT 900° F.

Basis: Bureau of Mines—American Gas Association Assay at 500° C

Product	lb.	Wt. %
Gas	140.0	7.00
Light oil	13.6	0.68
Tar	197.0	9.85
Char	1,437.4	71.87
Moisture	160.0	8.00
Liquor	52.0	2.60
	2,000.0	100.00

Table 4

CALCULATED NET DAILY YIELDS 8,520 TON/DAY COAL CARBONIZATION PLANT

Stream	Quantity
Coal carbonized, tons/day	8,520
Char product, tons/day	5,930
Fuel gas, million std.cu.ft./day @ 645 B.t.u./std.cu.ft.	15
Light oil, gal./day	6,400
Acid oil, gal./day	71,100
Creosote oil, gal./day	57,300
Pitch, gal./day	72,000
Sulfur, tons/day	67

Note: Quantities corrected for the char and gas consumed to provide heat for the process.

coal described in this paper would cost approximately $0.70/1,000 cu.ft. Use of the char with credit for the liquid products would reduce the cost of the gas to approximately $0.56/1,000 cu.ft. Though these figures are well above the current prices for natural gas in most areas, it should be pointed out that they are based on a relatively high-cost coal and could be considerably reduced if the plant were located in a coal-mine area. With a coal cost the order of $0.15/1,000,000 B.t.u. a combination carbonization and gasification plant could produce synthesis gas for less than the cost of producing it from natural gas in many areas in the United States.

Metallurgical Coke

In the preparation of metallurgical coke it is usually necessary to blend high-volatile and low-volatile coal to obtain a product having required coking characteristics. Good low-volatile blending coals are becoming scarce in the East and are nonexistent in some sections of the country. Low-temperature char has been suggested as a substitute for low-volatile coal and several workers are investigating this at the present time (*14*). In this application the economics could be based on a premium price for the char, allowing the sale of chemicals as complete by-products.

Summary

The cost of a fluidized bed, low-temperature carbonization plant processing 8,520 tons/day of Ohio bituminous coal has been estimated to be $11,500,000, including all auxiliary facilities. The plant was designed for the daily recovery of approximately 200,000 gal. of liquid products, 6,000 tons of char, 15,000,000 cu.ft. of fuel gas, and 67 tons of elemental sulfur. Using conservative market values for liquid products and fuel values for char, pitch, and gas, an annual gross profit of $3,568,000 before federal income taxes was estimated, indicating a return of 31 per cent on the initial investment.

Table 5

ANNUAL INCOME

Basis: Plant on stream 330 days/yr.

Product	Unit Price	Dollars/Yr.
Fuel gas	$0.258/million B.t.u.	824,000
Light oil	$0.16/gal.	338,000
Acid oil	$0.22/gal.	5,162,000
Creosote oil	$0.17/gal.	3,215,000
Pitch	$0.258/million B.t.u.	1,073,000
Sulfur	$20/ton	449,000
		11,061,000

Table 6

ANNUAL OPERATING COSTS

Raw materials	Dollars/Yr.
8,520 tons of coal/day @ $0.258/million B.t.u.	17,081,000
Credit for char 5,930 tons/day @ $0.258/million B.t.u.	12,440,000
Net cost of coal to carbonization plant	4,641,000
Utilities	
Electricity 1,400 kw. @ $0.01/kw.-hr.	111,000
Labor	
Direct operating 38 men at $2.25/hr.	187,000
Supervision @ 20%	37,000
Maintenance 16 men @ $2.25/hr.	79,000
Maintenance supervision @ 20%	16,000
Loading and shipping, 6 men @ $2.25/hr.	30,000
	349,000
Operating and Maintenance Materials @ 20% of total labor	70,000
Overhead	
Payroll @ 20% of total labor	70,000
Plant and administrative @ 50% of total labor and materials	210,000
	280,000
Fixed Costs	
Depreciation @ 10% of original plant cost	1,150,000
Insurance, local taxes, patents, research and development, etc.	460,000
	1,610,000
Sales and Advertising @ 15% of operating costs exclusive of raw materials	432,000
Total Operating Costs	7,493,000

Table 8

POWER AND ELECTRODE REQUIREMENTS

FOR TYPICAL ELECTROTHERMAL PROCESSES

Product	Power Requirement kw.-hr./ton	Electrode Requirement lb./ton
Aluminum	20,000-24,000	1,200-1,700
Calcium carbide (85%)	2,600- 6,000	40-70
Phosphorus	8,000-13,200	38
Silicon carbide	6,400- 7,700	....
Electric steel	500-800	12-14

By the use of equipment to coke the pitch and refine the acid oil and light oil streams, the annual gross profit could be substantially increased. Low-temperature carbonization appears to offer promise of substantial reduction in the cost of fuel and raw materials to operations involving the generation of electric power, the consumption of electrode carbon, and the production of synthesis and pipe-line gas. Low-temperature char may be an acceptable substitute for low-volatile coal in coking blends. At the present time processes are being developed which may usher in a new era of coal technology to rival the accomplishments of the petroleum industry in providing new markets, new products, and a new source of national prosperity.

Table 7

SUMMARY OF ECONOMIC FACTORS

Initial investment	$11,500,000
Gross annual sales	11,061,000
Operating cost	7,493,000
Annual profit	3,568,000
Per cent return on initial investment	31
Annual profit after federal income taxes of 52%	1,713,000
Per cent return on initial investment after taxes	15
Break-even price of char, cents/million B.t.u.	18.4

Basis: Plant on stream 330 days/year charging 8,520 tons/day of Ohio high volatile bituminous coal @ $0.258/million B.t.u. or $6.07/ton.

Acknowledgments

The authors express their appreciation here to V. F. Parry, Bureau of Mines;

A. D. Singh, Singh Co.; Clyde Berg, Union Oil Co.; and E. O. Keck, Texas Power and Light Co., for providing information during the early phases of this investigation.

Literature Cited

1. Alberts, L. W., J. S. Bardin, D. W. Beery, H. R. Jones, and E. J. Vidt, *Chem. Eng. Progress*, **48**, pp. 486-493 (1952).
2. Bristow, W. A., *J. Inst. Fuel*, **XX**, pp. 109-130 (April, 1947).
3. Creighton, H. J., and W. A. Koehler, "Principles and Applications of Electrochemistry," John Wiley & Sons, Inc., Vol. II (1935).
4. Fieldner, A. C., J. D. Davis, R. Thiessen, E. B. Kester, and W. A. Selvig, *Bur. Mines Bull.* 344 (1931).
5. Fieldner, A. C., J. D. Davis, *Bur. Mines Monograph* 5 (1934).
6. Fieldner, A. C., J. D. Davis, R. Thiessen, W. A. Selvig, D. A. Reynolds, R. E. Brewer, G. C. Sprunk, *Bur. Mines Tech. Paper* 584 (1938).
7. Gentry, F. M., "The Technology of Low Temperature Carbonization," The Williams and Wilkins Co. (1928).
8. Grossman, P. R., Paper presented at the Production and Chemical Conference of American Gas Association, New York (May 25-27, 1953).
9. Gunness, R. C., *Chem. Eng. Progress*, **49**, pp. 113-119 (1953).
10. Lesher, C. E., *Mining Eng.*, pp. 287-299 (March, 1952).
11. Newman, L. L., *Ind. Eng. Chem.*, **40**, pp. 559-582 (1948).
12. Parry, V. F., W. A. Landers, E. O. Wagner, J. B. Goodman, and G. C. Lammers, *Bur. Mines Repts. Invest.* 4954 (1953).
13. Perry, J. H., "Chemical Engineers' Handbook," McGraw-Hill Book Co., 3rd ed. Section 28 (1950).
14. Price, J. D., *Mining Eng.*, p. 716 (1953).
15. Rayner, J. W. R., *J. Inst. Fuel*, pp. 50-59 (March, 1952).
16. Riegel, E. R., "Industrial Chemistry," Reinhold Publishing Corp., New York, 3rd ed., Chapter 17 (1937).
17. Singh, A. D., and L. J. Kane, *Trans. Am. Soc. Mech. Engrs.*, **70**, pp. 957-964 (1948).
18. Skinner, L. C., H. R. Batchelder, and S. Kateel, *Ind. Eng. Chem.*, **44**, pp. 2381-2385 (1952).
19. Waggaman, W. H., and R. E. Bell, *Ind. Eng. Chem.*, **42**, pp. 276-286 (1950).
20. Zinn, R. E., *Chem. Eng. Progress*, **50**, No. 1, 3 (1954).
21. *Chem. Eng.*, **38**, pp. 219-222 (September, 1951).
22. *Chem. Eng.*, **59**, pp. 244-246 (March, 1952).
23. *Chem. Eng. News*, **31**, pp. 1490, 1701, 1830 (April, 1953).
24. *Petroleum Processing*, **7**, p. 45 (January, 1952).

Presented at 46th Annual Meeting of the A.I.Ch.E. at St. Louis, Mo.

FLUIDIZED BED HEAT TRANSFER

W. W. Wamsley and L. N. Johanson

University of Washington, Seattle, Washington

Heat transfer between gas and fluidized solids was investigated by the transient heating of cold particles in a hot gas stream. Transfer coefficients obtained from the rate of recovery of the gas temperature during the unsteady-state heating of the particles are a measure of the over-all performance of the fluidized bed. The results are interpreted in terms of the gas flow characteristics observed. It is shown that gas-fluidized beds cannot be considered equivalent to a uniformly expanded fixed bed, that a portion of the entry gas must be regarded as effectively by-passing the solid material present.

The number of papers dealing with heat transfer in fluidized beds which have appeared in recent literature reflect a growing interest in the fluidized bed as a versatile processing tool, but despite all these contributions the mechanism of heat transfer and the magnitude of the heat transfer coefficients are not established with any certainty.

The mechanism of heat and mass transfer in fluidized beds was first proposed to be analogous to that in an expanded fixed bed. Attempts were therefore made to correlate the data utilizing the *j*-factor concepts originated by Colburn (*4*), a method of correlation that had met with noteworthy success when applied to flow through packed beds (*8, 17*). Its extension to fluidized beds by allowing for the much higher fraction voids often reported seemed a logical approach; however, it has revealed some serious discrepancies (*20, 12, 3*), and it is now apparent that a gas-fluidized bed cannot be considered analogous to a packed bed, that is, as a relatively uniform dispersion of particles through which the fluid passes with little mixing or by-passing.

Bubbling of the gas through the solid has been observed by numerous investigators (*18, 25, 1*). The terms *fluidization quality* (*18*) and *fluidization efficiency* have been applied, in some cases in a quantitative manner (*11*), and these definitions classify such bubbling fluidization as being less efficient and desirable than the type of fluidization termed *particulate* and observed, for example, in the fluidization of solids of normal density with liquids. However particulate fluidization has not been observed, or even approached, in the usual gas-fluidized systems, and recent observations have indicated that the bubbling action should be accepted as normal and considered in any quantitative studies of gas-phase fluidization.

For complete tabular data, order document 4253 from A.D.I. Auxiliary Publications Photoduplication Service, Library of Congress, Washington 25, D. C., remitting $1.25 for microfilm or $1.25 for photoprints.

W. W. Wamsley is at present with Du Pont Photo Products Division, Parlin, N. J.

Previous Work

It is well to distinguish clearly between particle-to-fluid heat transfer, the subject matter of this paper, and heat transfer between the fluidized bed and a confining surface.

Leva and Grummer (*13*) have summarized essentially all the work which has been reported in the latter field. Since the appearance of their survey, additional data have been published by Dow and Jakob (*5*) and Bartholomew and Katz (*2*). A recent contribution by Van Heerden, Nobel, and Van Krevelen (*11*) stresses the complexity of the problem and points out the poor agreement among various researches in this field.

Studies on the transfer of heat between the solid and fluidizing gas have been less numerous. Kettenring, Manderfeld, and Smith (*12*) reported the first work specifically intended to measure particle-to-fluid heat transfer coefficients in gas-fluidized systems. Their technique involved simultaneous heat and mass transfer by air fluidization of wetted alumina and silica-gel particles. Temperature differences between the gas and solid were obtained as a function of bed height by assuming the gas temperature to be that of a bare thermo-

couple inserted in the bed and further assuming the solid temperature to be uniform throughout the bed and equal to the equilibrium temperature of the leaving gas. This information, together with the known rate of water evaporation and particle surface area, comprised the necessary data from which heat transfer coefficients were calculated. Actual values of h_p ranged from about 3 B.t.u./(hr.)(sq.ft.)(° F.) for 48-mesh particles at 300 lb./(hr.)(sq.ft.) to 10 B.t.u./(hr.)(sq.ft.)(° F.) for 14-mesh particles at 750 lb./(hr.)(sq.ft.).

An apparatus similar to that often used for measuring wall-to-bed coefficients was employed by Walton, Olson, and Levenspiel (*23*). Fluidized beds of crushed coal were externally cooled by a water jacket and thereby maintained at a temperature lower than that of the inlet gas. Heat transfer coefficients were based upon gas temperatures as indicated by a traveling high-velocity thermocouple near the bottom of the fluidized bed. Obviously solid temperatures could not be measured directly. Accordingly, maximum and minimum heat transfer coefficients were obtained, depending upon whether the solid temperature was taken as that of a bare thermocouple inserted in the same region at the bottom of the bed (maximum coefficient) or assumed equal to the equilibrium bed temperature, above the region in which gradients were observed (minimum coefficient).

Eichhorn and White (*6*) used dielectric heating to maintain particle temperatures above those of the surrounding gas in fixed beds. Attempts to apply the same technique to fluidized beds met with little success, as the authors were unable to measure any temperature difference between solid and gas. They do imply, however, that transfer coefficients in fluidized beds are sufficiently high so that heat transfer calculations may be treated by means of a simple heat balance on the gas stream alone, or as though particle-to-fluid heat transfer is essentially instantaneous.

Work restricted to mass transfer between gas and fluidized solid has also been published (*20, 3*), and with sufficiently precise data on heats of vaporization involved such results could be compared with heat transfer results. This was not attempted in this work.

In all the previously described investigations, heat transfer experiments were carried out under steady-state conditions; that is, fluid and solid temperatures may have been a function of position but were not a function of time.

The solid temperature could not be measured but was assumed or estimated by means of a variety of methods. The accuracy (or validity) of the heat transfer coefficients thus obtained depended upon which of these assumptions was made, as there exist widely differing opinions as to whether a thermocouple inserted in a fluidized bed indicates the temperature of the fluid or the solid or some intermediate temperature.

Unsteady-state Experimental Technique

In order to avoid estimating the solid temperature, experiments were conducted on the unsteady-state heating of solids with gas. Provided heat losses are negligible or can be accounted for, the original solid temperature together with a heat balance and a time history of the outlet gas allows calculation of the solid temperature at any time.

If the solid to be fluidized and the fluidizing gas can be brought together with sufficient rapidity, heat interchange before proper fluidization is established should be negligible. No significant difference in fluidization mechanism should exist between such a transient technique and the usual steady-state techniques, provided the properties of the fluidizing medium are not altered appreciably by the change in temperature with time. The heat-transfer coefficients obtained should therefore be comparable with and applicable to steady-state heat transfer in fluidized beds.

The solids used were glass beads, crushed alumina, and Dowex-50, with particle sizes ranging from 16/20 to 100/115 mesh. Air and carbon dioxide were the fluidizing mediums, and superficial mass velocities were varied from 100 to 600 lb./(hr.)(sq.ft.). The column diameter (2⅜ in.) was not varied.

With the exception of five runs using the system carbon dioxide–glass spheres, air was used as the fluidizing medium for all runs. Variables investigated included particle size, mass velocity of gas, temperature level of operation, and quantity of solids fluidized (or static bed height).

APPARATUS

The experimental apparatus consisted principally of a column in which fluidization and heating of the particles took place, a device to introduce cold particles into the hot gas stream, and a thermocouple system with which to measure the rate of change of the outlet gas temperature.

Figure 1 is a schematic diagram of the experimental setup. Incoming gas was first passed through a glass wool filter to remove any suspended foreign matter. A pressure regulator controlled the upstream pressure of a sharp-edged orifice which was used to measure the gas flow rate. The orifice was calibrated against a Thomas flowmeter and a previously standardized bellows-type gas meter. After passing the orifice, the gas was either humidified or dried, depending on the type of particle which was being fluidized. The humidifier was simply a fixed bed of water-saturated porous 4-mesh catalyst pellets, 8 in. deep and 4 in. in diam. Drying was accomplished in a 2½-in.-diam. column containing 1 lb. each of calcium chloride, Drierite, and activated alumina in series as a fixed bed. A 140-wt. electric heater, regulated by a Sola constant-voltage transformer, maintained a constant heat input to the gas. Hot gas passed from the heater to the main column through a calming section. A device for suddenly introducing cold particles into the hot gas stream was mounted directly above the main column. Construction details of this device are shown in Figure 2. The solid to be fluidized was supported by the upper of two cellophane diaphragms, an air space between this and a second diaphragm serving to insulate the solid thermally from the fluidizing gas. Both diaphragms could be severed simultaneously by means of nichrome-wire heaters controlled by a push button. Before particles were admitted the

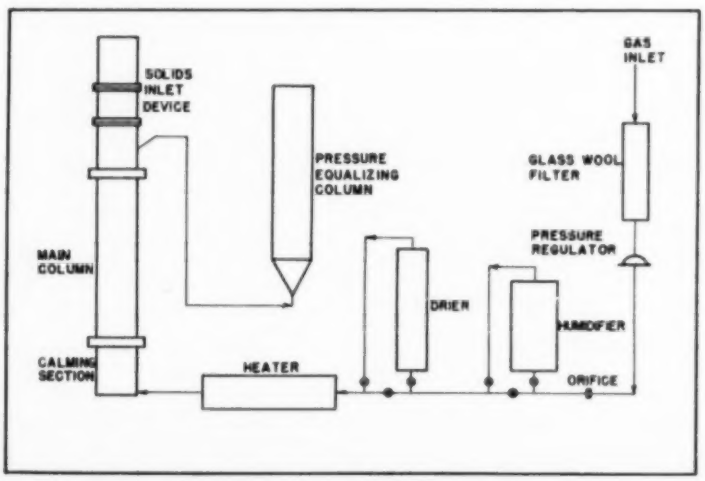


Fig. 1. Schematic diagram of experimental apparatus.

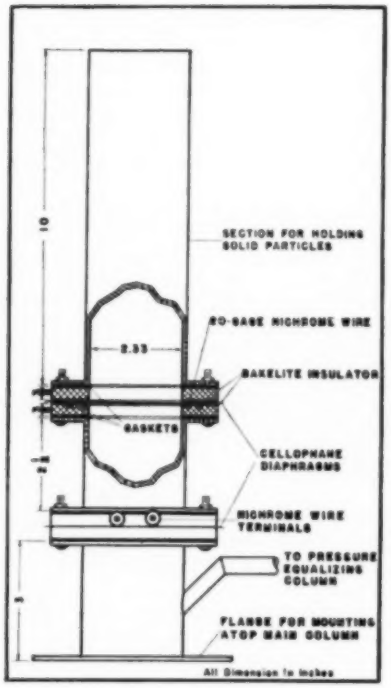


Fig. 2. Device for introducing particles into fluidization column.

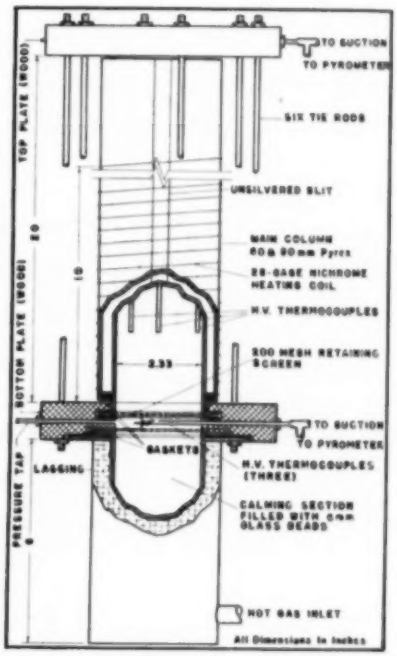


Fig. 3. Details of fluidization column.

gas was passed through a ½-in. pipe to a pressure-equalizing column of the same size and containing the same quantity of solids as the main column, in order to avoid an upset in flow rate upon the addition of particles to the main column. Upon severance of the diaphragms a new passage the same diameter as the main column became available for the flow of exit gas, which thus effectively by-passed the second, or pressure-equalizing, column.

Details of the fluidizing column proper are shown in Figure 3. A flat velocity profile at the fluidized-bed entrance was attained by means of a glass-bead-packed calming section, as verified by velometer readings taken above the supporting screen before the solid was admitted. Readings differed by no more than 3% from wall to center. Inlet-gas temperatures were measured by three high-velocity copper-constantan couples, encompassing equal column areas from wall to center between calming section and fluidized bed. A similar set of couples on a movable support measured outlet-gas temperatures. Thermocouple readings were averaged by connecting in parallel and read periodically by means of a Foxboro portable pyrometer, model No. 1105, with a 250° F. scale range. Couples and pyrometer were calibrated in place by means of a potentiometer and double-throw switch. Heat losses were minimized by means of a silvered double glass wall with a compensating electric heater surrounding the outer wall. The latter was ordinarily adjusted prior to the beginning of a run so that the equilibrium temperature of the outlet gas would approximately equal the inlet-gas temperature.

Table 1.—Properties of Solid Particles

Particle	Shape	Average diam., in.	Density, lb./cu.ft.	Specific heat, B.t.u./(lb.)(° F.)	Specific surface, sq.ft./lb.
Glass beads	Spherical				
32/35 mesh[1]		0.0179	163.9	0.196	24.4
60/65 mesh		0.0085	159.8	0.196	52.7
100/115 mesh		0.00539	161.6	0.199	82.3
Crushed alumina[2]	Irregular				
16/20 mesh		0.036	98.0[4]	0.24[5]	20.5
32/35 mesh		0.018	98.0	0.24	41.0
60/65 mesh		0.009	98.0	0.24	82.2
Dowex 50[3]	Spherical with				
20/24 mesh	some broken	0.030	95.5	0.324[6]	25.0
28/32 mesh	particles	0.021	95.5	0.324	35.4
32/35 mesh		0.018	95.5	0.324	43.9

[1] Tyler standard screens.
[2] Dehydrated by heating for 4 hr. at 450° F.
[3] Dried by fluidizing with air at same conditions as used in experimental run.
[4] Apparent density based on particle volume including internal void space.
[5] Value given by Aluminum Company of America.
[6] Assumed equal to specific heat of polystyrene.

EXPERIMENTAL PROCEDURE

Before the beginning of a run the initial solids temperature, as measured in place in the solids-admission device, was essentially that of the room; inlet-gas temperatures were varied from 114° to 171° F. A run was begun with gas at the proper temperature and velocity flowing through the pressure-equalizing column by simultaneously starting an electric timer and partially severing the cellophane diaphragms with the electrically heated wire to allow the solids to drop past the outlet thermocouples and into the fluidization column.

The outlet-gas temperature was read as a function of time, and the equilibrium outlet temperature attained was noted, as were the pressure drop through the bed and other pertinent data. Mechanical lag of the pyrometer and heat gain by the solids during admission were found to be negligible under the experimental conditions.

Properties of the solids used are summarized in Table 1. Glass spheres were used for the basic runs, in order that surface area, density, and heat capacity of the solid could be known with reasonable certainty. Crushed alumina and spheres of ion exchange resin (Dowex 50) were used to determine the effect of particle shape, roughness, and density upon the heat transfer coefficient. After screening, glass-particle sizes were measured by micrometer or microscope, depending on the size. Density and heat capacity of the glass particles were determined by use of water-submersion and water-calorimeter methods respectively. Diameters listed for alumina and Dowex particles are the averages of the two screen openings. Alumina heat capacity was that given by the manufacturer (Alcoa), and alumina density was based on the measured external void volume of a packed bed of water-saturated particles. Dowex-50 density was based on the weight of 1,500 measured particles. Dowex-50 heat capacity was assumed equal to that of polystyrene, verified later as being of the proper magnitude by comparing column-heat balances for Dowex with those for glass. The specific surface of the glass and Dowex spheres was calculated, and that of alumina was assumed equal to that of spheres of the same average mesh size. This assumption underestimates the actual surface of the alumina particles and therefore overestimates the corresponding transfer coefficients. The assumption was accepted, however, to facilitate comparison of results with those of Kettenring, Manderfeld,

and Smith, who used this assumption for crushed alumina.

Air was used for the basic runs for reasons of convenience. Carbon dioxide was used for a few runs, mainly to determine the effect of gas density. It was found necessary to humidify the gas used to avoid electrostatic effects when glass beads were fluidized. Such effects were minor with the alumina and resin particles, which were instead brought to equilibrium moisture content with the gas used, prior to making a run, to minimize anomalous results due to either evaporation or adsorption of water. In the case of alumina the gas used was bone-dry air from the drying column.

Unsteady-state Equations

Transient heating of a solid with a gas has been used to evaluate heat transfer coefficients in fixed beds (*7, 16, 21*); however, because of differences in solid and fluid temperature gradients involved, equations for fixed beds are not applicable to fluidized beds. Equations necessary to evaluate data for fluidized beds are therefore considered briefly here.

An ideal case may be visualized for which it is possible to develop relations allowing calculation of heat transfer coefficients in a straightforward manner. The following assumptions serve to define the simplified case:

1. The thermal properties of the gas and solid are independent of temperature.
2. Temperature gradients within the particle are negligible compared with surface-film gradients.
3. Sufficient particle mixing occurs so that at any given time the temperature of the solid is uniform throughout the bed.
4. Heat losses are negligible; that is, heat interchange takes place only between the particles and the fluidizing medium.
5. The gas passing through the bed is perfectly mixed so that at any given time the gas temperature everywhere within the bed is equal to the outlet temperature.

The propriety of these assumptions will be fully considered later. Equations are written for the case in which cold particles of mass W at some uniform initial temperature T_o are heated by hot gas which enters the bed at a mass rate w and a constant temperature t_i but leaves at a variable temperature t. The treatment is also applicable to the cooling of hot particles, which was not investigated experimentally.

The two fundamental relations are

$$wc_{pg}(t_i - t) = h_p A(t - T). \quad (1)$$

$$wc_{pg}(t_i - t)d\theta = Wc_{ps}dT. \quad (2)$$

for the instantaneous rate of heat transfer and the differential quantity of heat transferred, respectively. Equation (*2*) may be integrated graphically from a knowledge of variation of $(t_i - t)$ with time. The resulting solid temperature T may be used to solve Equation (1) for the desired transfer coefficient h_p. Graphical integration can be avoided, however, by differentiating Equation (1) and substituting the resulting value for dT into Equation (*2*). Equation (3) results:

$$(h_p A + wC_{pg})\frac{dt}{t_i - t} = h_p A \frac{wc_{pg}}{Wc_{ps}}d\theta \quad (3)$$

which can be integrated to give

$$\ln \frac{(t_i - t)}{(t_i - t)_o} = -hpA\frac{wc_{pg}}{Wc_{ps}(h_p A + wc_{pg})}\theta \quad (4)$$

where $(t_i - t)_o$ is the temperature difference between inlet and outlet gas at zero time when particles are at their initial temperature T_o. Equation (4) can also be written

$$(t_i - t) = \beta e^{-\alpha\theta} \quad (5)$$

where α and β are defined as

$$\alpha = \frac{h_p A wc_{pg}}{Wc_{ps}(h_p A + wc_{pg})} \quad (6)$$

$$\beta = (t_i - t)_o \quad (7)$$

Thus plotting the logarithm of $(t_i - t)$ vs. time should yield a straight line, the slope of which $(-\alpha)$ governs the value of the heat-transfer coefficient h_p. This is fortunate, since it enables one to obtain the transfer coefficients from data of the central portion of a run, where experimental accuracy is greatest. During the initial seconds of operation the temperature cannot be followed with precision. At the end of a run, as equilibrium is approached, the value of $(t_i - t)$ becomes very small and experimental errors are appreciable.

If the particle-to-fluid heat-transfer coefficient is infinite, Equations (6) and (*7*) become

$$\alpha_{h_p=\infty} = \frac{wc_{pg}}{Wc_{ps}} \quad (8)$$

$$\beta_{h_p=\infty} = (t_i - T_o) \quad (9)$$

These equations serve to define the limit for extremely rapid heat transfer and indicate that the slope of the gas-temperature-recovery curve would depend only on the relative heat capacity of gas and solid.

The first three assumptions upon which Equations (1) to (9) are based are the ones usually made in fluidized bed work unless a portion of the bed is being deliberately cooled or heated, as in a water-jacketed reactor (*23*). Heat capacity of gas and solid varied less than 2% over the extremes of temperature of this investigation. It can be shown for the largest particles used of the low conductivity material, glass, that the temperature gradient through the gas film is more than fifty times that through the solid, using any of the published values for heat transfer coefficient. Unlike most steady-state experiments, the temperature of solids used in these transient heating experiments can be changed only by the gas stream. The heat capacity of the solid is so great compared with that of the surrounding gas that a solid particle can traverse the fluidized bed several times without changing temperature more than 1° F. Since all particles were initially at the same temperature, the assumption of uniform solid temperature is therefore reasonable.

The last two assumptions, of negligible heat losses and complete mixing of gas, require more detailed comment. It is difficult to eliminate wall heat losses (or gains) in unsteady-state transfer, even with a compensating heater, except for the ideal situation of negligible wall heat capacity, because of the change in temperature level of the fluidized bed with time. Heat losses were not negligible in some of this work, as indicated in part by differences between inlet- and outlet-gas temperature after bed equilibrium had been attained. However, if the assumption is made that heat losses at all times during the run are of the same magnitude as the losses after equilibrium has been attained, a correction can be made simply by substituting t_e for t_i. This implies that t_e is a fictitious

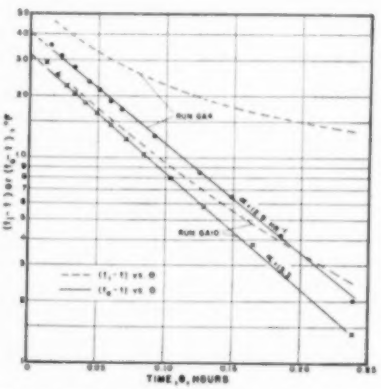


Fig. 4. Effect of heat losses on recovery curves and correction of inlet gas temperature.

Run GA4 No compensating heater	Run GA10 Compensating heater used
t_i = 148° F.	t_i = 142° F.
t_e = 137° F.	t_e = 141° F.
w = 8.15 lb. air/hr.	w = 8.38 lb. air/hr.

Table 2.—Typical Time-Temperature Data

θ = time, hr. × 10^3 Run GA 10		t = outlet-gas Temperature, ° F. Run AA 36	
θ	t	θ	t
12.5	111.5	12.0	111.5
20.8	115.7	16.4	115.7
26.4	118.1	22.5	119.9
32.8	119.9	37.2	126.3
40.0	122.3	41.6	128.6
48.9	124.3	50.8	130.5
59.8	126.3	60.3	132.8
70.9	128.6	71.6	135.0
83.9	130.5	86.1	137.0
103	132.8	108	139.4
128	135.0	136	141.4
165	137.0		

Table 3.—Typical General Data

Run [1]	Weight of solids, lb.	Inlet-gas temp., ° F.	Equil. gas temp., ° F.	Initial solid temp., ° F.	Void fraction of static bed	Slope of recovery curve, α	Intercept recovery curve, β
GA4	0.50	148.1	137.0[2]	77.0	0.41	12.9	41.7
GA10	0.50	141.4	140.8	77.8	0.41	13.2	31.4
GA14	0.50	144.5	142.1	80.4	0.40	11.3	27.2
GA16	0.50	143.4	141.8	76.5	0.40	16.5	37.1
GA22	0.70	137.0	136.4	80.7	0.40	13.7	37.1
GC24	0.50	142.9	139.8	76.8	0.40	21.8	39.2
DA30	0.31	145.7	143.9	80.4	0.42	15.8	32.6
AA36	0.44	145.2	144.3	83.0	0.47	18.0	34.1

[1] See Table 4 for run notation.
[2] Compensating heater not used.

inlet temperature, which would be attained by the gas after giving up some of its heat to the wall. The result of such a correction is shown in Figure 4, which is a plot of Equation (5) for two runs made under similar conditions except that the compensating heater was not used in run *GA*4.

The dotted lines show that neither run plots as a straight line, as Equation (5) implies. If t_e is substituted for t_i in each case, however, the points shown result and can be well represented by the solid lines. Furthermore, the lines are nearly parallel, as would be expected except for the influence of the slight difference in air velocity from considerations of the definition of α. Heat transfer coefficients calculated for these runs are h_p = 0.13 B.t.u./(hr.)(ft.)(° F.) for run *GA*4 and h_p = 0.14 B.t.u./(hr.)(ft.)(° F.) for run *GA*10. There was actually a heat loss to the wall in run *GA*4 and a heat gain from the wall in run *GA*10. Thus it is apparent that the value of transfer coefficient obtained with Equation (5) is not greatly affected by gross changes in the amount of heat loss or gain at the column wall, provided equilibrium outlet temperature is substituted for the inlet temperature. The value of the intercept β is affected by such changes, but this is of minor importance since β is not used in the evaluation.

The assumption of uniform gas temperature was made in order to use the outlet temperature in calculations involving driving force. This avoids the necessity of obtaining temperature readings within the bed. For steady-state transfer such an assumption is normally checked by simply moving a thermocouple about in the fluidized bed. In this work a comparison was made between a run based on outlet temperature and a run of similar conditions except that the outlet thermocouples were submerged to within ½ in. of the bottom of the bed, or over three quarters of the distance into the bed. To obtain consistent data in the latter case, it was necessary to stop the gas flow through the high-velocity couples except when

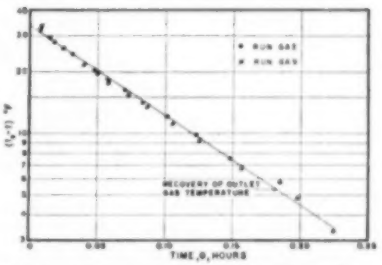


Fig. 5. Recovery curves showing effect of gas sampling position on indicated temperature.
Run GA2 Recovery of outlet Gas temperature w = 5.68 lb. air/hr.
Run GA9 Gas temperature 0.5 in. from bottom of fluidized bed w = 5.61 lb. air/hr.

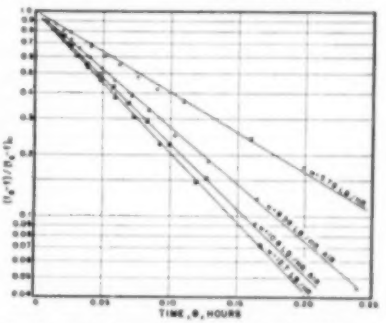


Fig. 6. Typical recovery curves showing effect of gas flow rate, for 0.5 lb. of 60/65-mesh glass spheres.

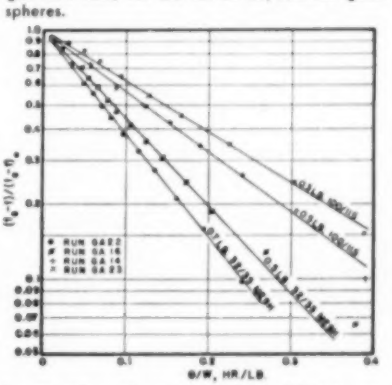


Fig. 7. Effect of varying static bed height on rate of recovery of gas temperature.

Run No.	W, lb. air /hr.	Static bed height, in.
GA22	10.5	2.9
GA16	10.6	2.1
GA14	8.4	2.1
GA23	8.3	1.3

a reading was being taken, to avoid build-up of particles on the thermocouple probe. The excellent agreement between the two runs (Figure 5) indicates that results based on the entire bed would be the same as results based upon any particular bed level. Actually it will be shown later that the assumption of a completely uniform gas temperature is inconsistent with other observations, and instead the gas temperature must be considered only as statistically uniform; that is, changes in temperature due to gas by-passing and bubbling are too rapid to be detected by the usual means.

Equations (5), (6), and (7), with t_i replaced by t_e, were used to evaluate heat transfer coefficients from the original data. Sample data are shown in Tables 2* and 3* and transfer coefficients are summarized in Table 4. Figure 6 is typical of the results obtained by plotting Equation (5). The negative slope α is seen to increase with increasing gas flow rate. Figure 7 is a similar plot, except for the appearance of solid weight W in the abscissa, showing the effect of varying the static bed height or weight of solids. Equation (5) predicts no change in slope with this variable. Clearly the mechanism of heat transfer is not completely defined by Equation (5).

The effect of temperature level of operation is merely to change the intercept without affecting the slope and corresponding transfer coefficient, in accordance with the derived equations, as illustrated in runs *GA*6, *GA*2, and *GA*3. With equilibrium outlet-gas temperatures of 107.4°, 125.6°, and 152.0° F., respectively, the heat transfer coefficients obtained are 0.16, 0.14, and 0.16 B.t.u.(hr.)(sq.ft.)(° F.). Thus, neither the amount of heat loss to the wall due to changing wall temperature nor the temperature level of operation affect the heat transfer coefficient significantly.

Transfer coefficients obtained are

* Complete tabulations of data, Tables 8 and 9, are on file with the American Documentation Institute as Document 4253.

Table 4.—Tabulation of Over-all Heat-Transfer Coefficients Calculated from Slope of Recovery Curves

Run [1]	Particle size, Tyler mesh	Superficial mass velocity, G, lb./(hr.)(sq.ft.)	Over-all heat-transfer coefficient, B.t.u./(hr.)(sq.ft.)(° F.)
GA11	32/35	284	0.48
GA16	32/35	358	0.36
GA22	32/35	355	0.42
GA15	32/35	419	0.41
GA19	32/35	509	0.42
GA2	60/65	192	0.14
GA18	60/65	195	0.11
GA4	60/65	275	0.13
GA10	60/65	283	0.14
GA13	60/65	358	0.13
GA20	60/65	429	0.13
GA9[2]	60/65	189	0.14
GA12	100/115	118	0.070
GA21	100/115	195	0.053
GA23	100/115	280	0.073
GA14	100/115	282	0.062
GA17	100/115	350	0.075
GC24	32/35	478	0.64
GC25	32/35	479	0.54
GC26	60/65	254	0.13
GC27	60/65	392	0.14
GC28	100/115	251	0.065
AA35	16/20	608	0.84
AA39	16/20	473	0.92
AA38	32/35	269	0.30
AA36	32/35	379	0.36
AA37	60/65	282	0.14
DA40	20/24	383	0.73
DA41	28/32	318	0.41
DA30	32/35	379	0.30

[1] First letter signifies particle used: G = glass beads, A = alumina, D = Dowex 50; second letter signifies gas used: A = air, C = carbon dioxide; number indicates sequence of runs.
[2] Gas-temperature thermocouples submerged to within ½ in. of bottom of bed.

shown as a function of gas velocity in Figure 8. The lines drawn are arithmetic average values, although they are very close to lines fitted by the method of least squares. It is therefore apparent that there is no noticeable effect of mass velocity of gas upon the heat transfer coefficient. The effect of particle size is shown in Figure 9. Averaged coefficients for the various mass velocities were used for each size shown. For the three sizes of glass spheres investigated, h_p varies as $D_p^{1.5}$. Little significance should be attached to the relative position of the curves for glass, alumina, and Dowex 50 in view of the assumptions made regarding the heat capacity of Dowex 50 and the surface area of alumina.

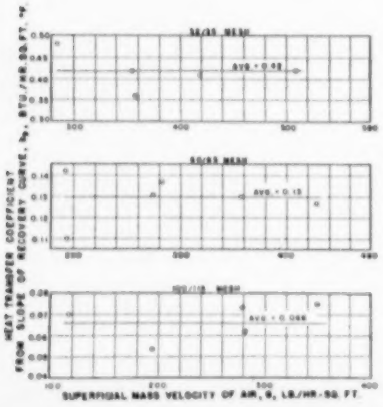


Fig. 8. Effect of air flow rate on heat transfer coefficients. Air-glass system.

Discussion

The most remarkable feature of the results is the extremely low magnitude of the coefficients. These are contrasted with previous steady-state measurements in Table 5 for similar ranges of particle diameter and flow rate.

The discrepancies between results obtained by the authors and those previously reported for fluidized beds are too great to be accounted for by differences in experimental technique. Theoretically the same coefficient of heat transfer should apply to both steady- and unsteady-state heating of fluidized solids; therefore it is more probable that these discrepancies are due to basic differences in interpretation of the experimental data.

Not only the authors' coefficients but those tenfold greater reported by others and included in Table 5 are less than would be expected for conduction through stagnant air. Calculations have been made (*5, 11*) to show that gas passing through a bed of particles this small should reach thermal equilibrium within a small fraction of a second, or within a fraction of an inch of the bottom of the bed. These calculations are based upon a value of 2 for the Nusselt group, h_pD_p/K (*19*). The same conclusions were reached by the authors for this system. The only explanation of the low coefficients is therefore that a substantial portion of the gas does not attain thermal equilibrium with the solid.

To verify this hypothesis the following experiment was performed. The

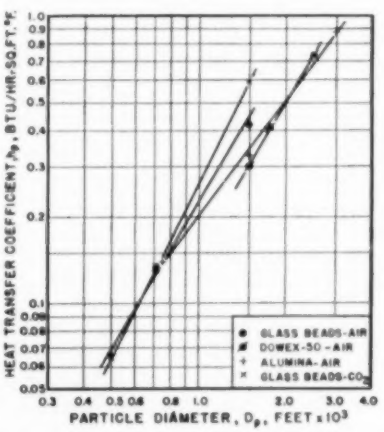


Fig. 9. Effect of particle diameter on heat transfer coefficients.

Table 5.—Comparison of Results with Previous Steady-State Measurements of Gas-Solid Heat-Transfer Coefficients for Fixed and Fluidized Beds and for Single Particles

Type of system	Max. range of h_p, B.t.u./(hr.)(sq.ft.)(° F.)	Effect of increasing gas flow rate	Effect of increasing particle size
Fluidized bed, present investigation	0.06-0.9	No effect	Increases h_p
Fluidized bed (12)	0.47-6.6*	Increases h_p	Increases h_p
Fluidized bed (23)	0.43-16*	Increases h_p	Increases h_p
Fixed bed (26)	20-130*	Increases h_p	Decreases h_p
Single particles (19)	15-95*	Increases h_p	Decreases h_p

* Range of h_p for some ranges of particle diameter and superficial mass velocity used in present investigation.

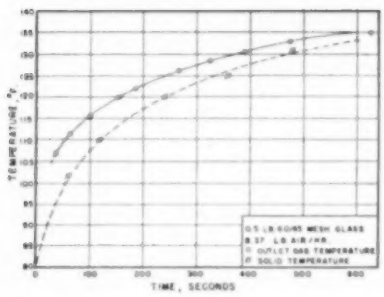


Fig. 10. Direct measurement of temperature difference existing between gas and solid.

time-temperature history of the outlet air during the heating of 0.5 lb. of 60/65-mesh glass spheres was determined in the usual manner. This run was then repeated six times, with the air flow rate, initial bed temperature, and inlet-air temperature being kept as nearly the same as possible in all cases. In each of the later runs the fluidizing air was turned off after a measured time interval, and simultaneously a single bare thermocouple was placed in the center of the now static bed. With no gas flowing through the bed, the bare thermocouple readings should quickly approach the solid temperature, since the air heat capacity is negligible compared with the heat capacity of the solid. The results of these measurements are shown in Figure 10. There is a consistent difference between the solid temperature thus measured and the measured temperature of exit or surrounding gas during fluidization. This is in qualitative agreement with transfer coefficients less than those for thermal conduction alone and indicates that the assumption of solid temperatures being equal to the measured temperature of the fluidized bed is untenable. This observed lack of approach of gas temperature to that of the solid, and the consequent low transfer coefficients obtained must instead be related to the by-passing of subtsantial quantities of gas without adequate contact with the solid.

Careful examination of the data of Kettenring, Manderfeld, and Smith (*12*) substantiates this conclusion. Their work involved the simultaneous transfer of heat and mass from wet alumina and silica-gel particles under steady-state conditions. Furthermore humidification was shown to be very nearly adiabatic. The temperature of the wet particles therefore should agree closely with the adiabatic saturation temperature of the dry inlet air. In all their reported experiments however the equilibrium bed temperature, which was assumed to equal the solid temperature, was from 10° to 20° F. higher than the saturation temperature. This phenomenon is in direct contrast to previously reported fixed-bed experiments (*26*) in which the solid particles rapidly reached the adiabatic saturation temperature and in which it was necessary to limit the bed height to a few particle diameters in order to prevent the outlet gas from becoming saturated. The only satisfactory explanation is, again, that true by-passing of the gas takes place. It is very probable that the temperature of the gas in the dense portion of the fluidized bed where most of the solid resides was less than the temperature of the rising bubbles. Such local and transient variations in the gas temperature would not have been detected by a single thermocouple inserted in the bed. On this basis it is apparent that the coefficients reported by Kettenring, Manderfeld, and Smith are based on an incorrect solid temperature. Therefore data from twelve of their runs chosen randomly were recalculated by means of the adiabatic saturation temperature as the temperature of the solid. In lieu of data on the particle-surface area, which they omitted, the following procedure was used. For one run, which was illustrated in detail, the particle area per unit bed height for 28/35-mesh particles was calculated from their Equation (*2*) and Figure 3. The total particle area for the recalculated runs was then found by use of an inverse proportionality between particle area per unit height and the square of the particle diameter, assuming that the bed height was always 5 in. (reported to vary from 4 to 6 in.). This procedure underestimates the particle area at low gas velocities and overestimates the particle area at high gas velocities. The recalculated coefficients are listed in Table 6 and plotted in Figure 11 together with the curve for the air-alumina runs of the present investigation.

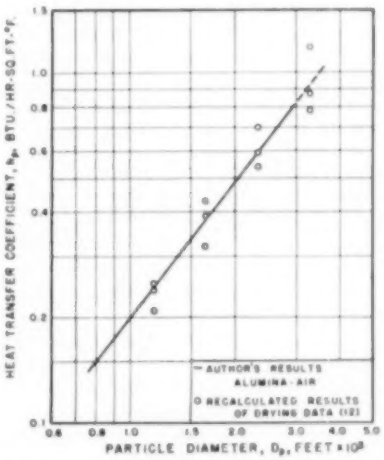

HEAT TRANSFER COEFFICIENT, h_p, BTU/HR-SQ FT-°F.
PARTICLE DIAMETER, D_p, FEET ×10²
AUTHOR'S RESULTS ALUMINA-AIR
RECALCULATED RESULTS OF DRYING DATA (12)

Fig. 11. Comparison of author's results with recalculated results of steady-state technique.

The agreement between the two sets of results is good but may be somewhat fortuitous in view of the assumptions involved in recalculating the data of Kettenring, Manderfeld, and Smith. Certainly, though, the recalculated overall coefficients are more nearly correct than the previously reported ones, since they are based on a more realistic value of the solid temperature.

Unfortunately it is not possible to recalculate the data of Walton, Olson, and Levenspiel (*23*) because there is no way of determining the true solid temperature in their experiments, since mass transfer was not involved. However, as with the experiments of Kettenring, et al., their assumption that the gas and solid come to equilibrium is subject to quesion, and hence their minimum coefficients, which are based on this assumption, could actually be too high.

A number of observations have been reported which are helpful in elucidating the actual mechanism of heat transfer consistent with observed results.

Gilliland and Mason have shown (*9*) that appreciable back mixing or circula-

Table 6.—Recalculated Coefficients from Data (12) Using the Adiabatic Saturation Temperature as the Temperature of the Solid

Run	Particle mesh size	Superficial mass velocity, lb./(hr.)(sq.ft.)	Heat transfer coefficients, B.t.u./(hr.)(sq.ft.)(° F.) Reported	Recalculated
36	14/20	356	4.2	0.87
29	14/20	499	6.7	0.78
122	14/20	584	7.3	1.18
41	20/28	336	3.5	0.59
58	20/28	422	4.5	0.54
53	20/28	494	5.9	0.70
151	28/35	308	3.3	0.32
163	28/35	432	3.6	0.43
113	28/35	575	6.0	0.39
73	35/48	360	3.0	0.21
102	35/48	422	3.3	0.25
97	35/48	626	5.9	0.24

tion of the gas in a fluidized bed occurs. They have also shown, however (*10*), that considerable by-passing of solid by the gas stream occurs and so the over-all result is an apparent approach to complete mixing. Wilhelm (*24*) estimates this fraction by-passed as from 40 to 70%. Toomey and Johnstone (*22*) propose that the fraction of gas directly contacting the solid in the continuous phase is that quantity required to initiate fluidization. Any gas in excess of this quantity is proposed to pass through the bed as a discontinuous phase in the form of bubbles.

This is in agreement with measurements of bed height performed in this laboratory. Because of large deviations and conflicting results reported for visual observation of bed height, a more quantitative method was selected. A vertical traverse of the static pressure within the fluidized bed was obtained by means of a probe attached to a two-liquid manometer. Any difference in pressure between a point within the bed and the region above the bed is almost entirely due to the weight of solid above the probe. Extrapolation of observed results to zero manometer reading indicated that the average bed height was approximately the same as that of the packed bed before fluidization. These results were not affected by either particle size or mass velocity.

There is no quantitative information available which allows one to estimate the bubble size, rate of rise through the bed, or rate of intermixing with gas of the continuous phase. The appearance of these bubbles, however, indicates they are very large in comparison to the size of the particles and consequently have much less specific area available for heat transfer. One approximation which can therefore be useful in comparison of theory and data is to assume that such bubbles pass through the bed with negligible heat interchange with the solid. The gas passing through the bed as a continuous phase can be assumed to be in equilibrium with the solid, in accordance with the conduction calculations previously discussed.

Data from the present investigation can be used to test this proposal. The exit temperature of the by-passed gas will be that of the inlet gas, and the continuous phase will be at the solid temperature. Thus at any time during the transient heating of fluidized solids, the temperature of the blended exit gas t can be written in terms of the solid temperature T, the inlet temperature t_i, and the flow rates of the component streams:

$$wt = w_{mf}T + (w - w_{mf})t_i \qquad (10)$$

Rearrangement of Equation (10) yields

$$1 - \frac{w_{mf}}{w} = 1 - \frac{(t_i - t)}{(t_i - T)} \qquad (11)$$

Substitution of the value of T as given by Equation (1) into Equation (11) leads to

$$1 - \frac{w_{mf}}{w} = 1 - \frac{h_p A}{h_p A + wc_{pg}} \qquad (12)$$

The right-hand side of Equation (12) is equal to $(1 - a/a_{hp=\infty})$, as can be seen from the expression for a and $a_{hp=\infty}$ [Equations (6) and (8)]. It is apparent that the same result would be obtained if the effective inlet temperature t_e were used in place of t_i since all temperature terms drop out. Thus the proposal that all the gas passing through the bed in excess of that required for incipient fluidization truly by-passes the solid can be checked with the present experimental data by comparing values of $(1 - a/a_{hp=\infty})$ with values of $(1 - w_{mf}/w)$ or $(1 - G_{mf}/G)$. Such a comparison is given in Table 7. The gas flow rates at minimum fluidization were taken from the data of Lewis, Gilliland, and Bauer (*15*) for similar air-glass bead systems. It is to be noted that no distinction has been made between the gas flow rate at minimum fluidization and that at incipient two-phase fluidization. This should be of little consequence, however, since particulate fluidization in gas-solid systems occurs over a very narrow range of flow rates.

For each of the bead sizes and at all the gas flow rates used, it is seen from Table 7 that $(1 - a/a_{hp=\infty})$ is less than $(1 - G_{mf}/G)$. This means that if the low gas-solid heat transfer coefficients in gas-fluidized beds are to be explained on the basis of true and simple by-passing, then the fraction of gas by-passed is less than $(1 - G_{mf}/G)$. If, however, the two-phase theory of fluidization is to be accepted as correct, with G_{mf} as the mass velocity of the continuous phase, then the results shown in Table 7 indicate that the gas in the discontinuous phase is not completely by-passed insofar as gas-solid heat transfer is concerned; that is, some transfer must take place between the rising bubbles and the solid in the dense portion of the bed.

Of interest is the fact that for a given gas flow rate, Table 7 shows that both fractions, $(1 - a/a_{hp=\infty})$ and $(1 - G_{mf}/G)$, increase with decreasing particle size. Thus a reasonable explanation for decreasing heat transfer coefficients with decreasing particle size (the inverse of results for fixed beds and single particles) is that smaller particles permit a larger fraction of the entry gas to be effectively by-passed. This is to be contrasted with the statement of Kettenring, Manderfeld, and Smith (*12*) which attributes this phenomenon to lower slip velocities of the smaller particles. However, to explain the constancy of the apparent over-all heat transfer coefficients with increasing gas velocities, it is necessary for by-passing to become relatively less detrimental at higher flow rates. This is not necessarily a contradiction to the two-phase fluidization theory, for if the gas in the discontinuous phase must be physically transferred into the continuous phase in order to react with the solid, such transfer should be enhanced by higher gas velocities and accompanying greater particle turbulence.

The effect of varying the static bed height is also made more apparent by considering that true by-passing of the solid occurs. In Equation (1) h_p is based on the temperature difference between the solid and the outlet gas. A correct and generally applicable coefficient is thus defined if the gas and solid temperature are uniform throughout the bed. But owing to by-passing, whereby the gas flow through the bed may be regarded as made up of two separate streams, one at the temperature of the solid and the other at a substantially different temperature, it is only the average

Table 7.—Data to Test Assumption that Gas Flow in Discontinuous Phase Completely By-Passes Solid

Run	Mesh size	G, lb./(hr.)(sq.ft.)	G_{mf},* lb./(hr.)(sq.ft.)	$\left(1 - \frac{a}{a_{hp=\infty}}\right)$	$\left(1 - \frac{G_{mf}}{G}\right)$
GA 11	32/35	284		0.25	0.47
GA 16		358	149	0.36	0.58
GA 15		419		0.37	0.64
GA 19		509		0.42	0.71
GA 18	60/65	195		0.32	0.79
GA 10		283	41.5	0.36	0.85
GA 13		358		0.42	0.88
GA 20		429		0.48	0.90
GA 12	100/115	118		0.22	0.84
GA 21		195	19.2	0.38	0.90
GA 14		282		0.44	0.93
GA 17		350		0.45	0.95

* From data of Lewis, Gilliland and Bauer (*15*).

or bulk gas temperature that is apparently uniform. However, the corresponding heat transfer coefficients calculated from the rate of recovery of the blended outlet gas temperature are still useful in predicting the over-all bed performance. It would be expected, though, that heat transfer between the solid and rising gas bubbles, or discontinuous phase, should become significant as the bed height is increased. Thus the effect of changing the bed height is to change the relative importance of heat transfer to the solid from the gas in the continuous and discontinuous phases.

Conclusions

Two extreme mechanisms of gas-solid heat transfer in gas-fluidized beds have been considered, one whereby all the entry gas was assumed to experience equal gas-solid contact by passing through a uniformly expanded bed of particles and the other in which all the gas flow in excess of that required for minimum fluidization was regarded as taking no part in gas-solid heat transfer. The data obtained from the transient heating of fluidized particles indicate a mechanism between these two extremes but more nearly conform to the latter case and cannot be explained except on the basis of incomplete gas-solid contact.

The heat transfer coefficients obtained are not intended to be used indiscriminately in calculating gas-solid heat transfer in fluidized beds. Because of the extreme heterogeneity of gas-fluidized beds, it is doubtful if a generally applicable correlation in terms of the usual correlating variables could be attained. It is believed, however, that the values of the over-all heat transfer coefficients obtained, and their interpretation leading to an estimate of the effective fraction of gas by-passed, are of practical importance in all problems involving the gross behavior of gas-fluidized beds. Thus if a fluidized bed is to be used as a heat transfer device under conditions similar to those employed in the present investigation, the expected heat interchange between the solid and gas can be calculated from values of the transfer coefficients obtained and the inlet temperatures of the gas and solid. Also, if a solid-catalyzed reaction is to be carried out using a gas-fluidized bed, a knowledge of the fraction of gas by-passed is of paramount importance in estimating the expected conversion of reactants.

It is expected that the effective fraction of by-passed gas would be a function of the height of the fluidized bed. This effect was investigated to a limited extent by varying fixed-bed heights over a twofold range. Further data using much larger ratios must be obtained before over-all heat transfer coefficients can be predicted with confidence for industrial-size reactors.

Use of the over-all coefficients of this work is not recommended for application to point conditions at the solid-fluid interface; for example, if the temperature level of a fluidized catalyst particle is required, based upon the heat of reaction and temperature of the gas in the continuous phase surrounding the particle, use of these coefficients would underestimate the rate of transfer. Further data are required to establish proper valves for use in such a case. Until such data are obtained, the use of coefficients for conduction or free convection is recommended. Though conservative, they indicate that substantial equilibrium is attained between solid and continuous phase gas for most gas-fluidized systems.

Acknowledgment

The authors are indebted to C. F. Gerald, of the Universal Oil Products Co., who contributed greatly during early stages of this work.

Notation

For run nomenclature see Table 4.

A = total particle-surface area, sq.ft.

c_p = specific heat B.t.u./(lb.)(° F.); subscript g refers to gas; subscript s refers to solid particles.

D_p = particle diameter, ft.

G = superficial mass velocity of fluidizing gas, lb./(hr.)(sq.ft.); subscript mf refers to mass velocity of minimum fluidization.

h_p = gas-to-particle heat transfer coefficient, B.t.u./(hr.)(sq.ft.)(° F.), defined by Equation (1).

k = thermal conductivity of fluidizing medium, B.t.u./(hr.)(ft.)(° F.).

t = gas temperature, ° F.; no subscript refers to outlet gas temperature at any time during transient heating of fluidized particles; subscript i refers to inlet gas temperature; subscript e refers to equilibrium gas temperature.

T = temperature of solid at any time during transient heating, ° F., assumed uniform throughout bed; subscript o refers to solid temperature at zero time.

w = weight rate of flow of fluidizing gas, lb./hr.; subscript mf refers to flow rate of minimum fluidization.

W = weight of solid particles fluidized, lb.

Greek Letters

α = negative slope of gas-temperature-recovery curve, hr. $^{-1}$, defined by Equations (5) and (6) with t_i replaced by t_e. $\alpha_{h_p=\infty}$ equals limiting value defined by Equation (8).

β = zero time intercept of gas-temperature-recovery curve, ° F., defined by Equation (7) with t_i replaced by t_e. $\beta_{h_p=\infty}$ equals limiting value defined by Equation (9).

θ = time, hr.

Literature Cited

1. Askins, J. W., G. P. Hinds, and F. Kunreuther, *Chem. Eng. Progr.*, **47**, 401 (1951).
2. Bartholomew, R. N., and D. L. Katz, *Chem. Eng. Prog. Symposium Series*, **48**, No. 4, 3 (1952).
3. Chu, J. C., J. Kalil, and W. A. Wetteroth, *Chem. Eng. Progr.*, **49**, 141 (1953).
4. Colburn, A. P., *Trans. Am. Inst. Chem. Engrs.*, **29**, 174 (1943).
5. Dow, W. M., and M. Jakob, *Chem. Eng. Progr.*, **47**, 637 (1951).
6. Eichhorn, J., and R. R. White, *Chem. Eng. Progr. Symposium Series*, **48**, No. 4, 11 (1952).
7. Furnas, C. C., *Trans. Am. Inst. Chem. Engrs.*, **24**, 142 (1930).
8. Gamson, B. W., G. Thodos, and O. A. Hougen, *Trans. Am. Inst. Chem. Engrs.*, **39**, 1 (1943).
9. Gilliland, E. R., and E. A. Mason, *Ind. Eng. Chem.*, **41**, 1191 (1949).
10. *Ibid.*, **44**, 218 (1952).
11. Van Heerden, C., A. P. P. Nobel, and D. W. Van Krevelen, *Ind. Eng. Chem.*, **45**, 1237 (1953).
12. Kettenring, K. N., E. L. Manderfeld, and J. M. Smith, *Chem. Eng. Progr.*, **46**, 139 (1950).
13. Leva, M., and M. Grummer, *Chem. Eng. Progr.*, **48**, 307 (1952).
14. Leva, M., M. Grummer, M. Weintraub, and M. Pollchik, *Chem. Eng. Progr.*, **44**, 619 (1948).
15. Lewis, W. K., E. R. Gilliland, and W. C. Bauer, *Ind. Eng. Chem.*, **41**, 1104 (1949).
16. Löf, G. O. G., and R. W. Hawley, *Ind. Eng. Chem.*, **40**, 1061 (1948).
17. McCune, L. K., and R. H. Wilhelm, *Ind. Eng. Chem.*, **41**, 1124 (1949).
18. Morse, R. D., *Ind. Eng. Chem.*, **41**, 1117 (1949).
19. Ranz, W. E., and W. R. Marshall, Jr., *Chem. Eng. Progr.*, **48**, 173 (1952).
20. Resnick, W. E., and R. R. White, *Chem. Eng. Progr.*, **45**, 377 (1949).
21. Schumann, T. E. W., *J. Franklin Inst.*, **208**, 406 (1929).
22. Toomey, R. D., and H. F. Johnstone, *Chem. Eng. Progr.*, **48**, 220 (1952).
23. Walton, J. S., R. L. Olson, and O. Levenspiel, *Ind. Eng. Chem.*, **44**, 1474 (1952).
24. Wilhelm, R. H., *Chem. Eng. Progr.*, **49**, 150 (1953).
25. Wilhelm, R. H., and M. Kwauk, *Chem. Eng. Progr.*, **44**, 201 (1948).
26. Wilke, C. R., and O. A. Hougen, *Trans. Am. Inst. Chem. Engrs.*, **41**, 445 (1945).

CO_2 ABSORPTION

employing hot potassium carbonate solutions

H. E. Benson, J. H. Field, and R. M. Jimeson U. S. Bureau of Mines, Bruceton, Pennsylvania

To remove carbon dioxide from compressed gases at pressures of 200 to 300 lb./sq.in. gauge or higher, a hot concentrated solution of potassium carbonate is an efficient absorbent that minimizes steam consumption.

This process was developed to decrease the cost of removing carbon dioxide from synthesis gas in which it is not only a diluent, but also a depressant of catalyst activity. It is compared with the amine scrubbing process, and a pilot-scale unit is discussed.

For the development of a commercially useful Fischer-Tropsch process, economical removal of carbon dioxide from the synthesis gas, a mixture of hydrogen and carbon monoxide, has considerable importance. Carbon dioxide not only is a diluent of the synthesis gas but also is thought to be a catalyst poison when present in fairly large concentrations. Hence absorption of carbon dioxide is generally considered essential for purifying raw synthesis gas (obtained by gasification of coal with steam and oxygen and containing about 15% CO_2) and synthesis gas recycled to the synthesis reactor. About 320 cu.ft. of carbon dioxide is made per 1000 cu.ft. of pure synthesis gas. Approximately half of this carbon dioxide is in the raw gas; the remainder is formed during synthesis.

In the production of hydrogen from coal, steam, and oxygen, carbon dioxide scrubbing also plays an important part, as approximately 700 cu.ft. of carbon dioxide must be removed per 1000 cu.ft. of hydrogen. Of more immediate industrial interest is the removal of carbon dioxide from ammonia synthesis gas, from hydrogen made by the steam-methane reaction, and from synthesis gases used in the petrochemical industry.

In recent years, mono-, di-, and triethanolamine scrubbing solutions have replaced alkali carbonate solutions consisting of approximately 10% aqueous sodium carbonate or 15% potassium carbonate (*5*). This study deals with the use of higher absorption temperatures which, because of solubility considerations, permit greater concentrations of potassium carbonate. Both amine and carbonate solutions require regeneration at a higher temperature than that of absorption. A greater capacity for carbon dioxide and lower consumption of regeneration steam make the amine process preferable to the early alkali carbonate process. When the impure gas is under pressures exceeding 200 lb./sq.in., water may be used as the absorbent. Because of the large amount of water as compared with amine required pumping costs are relatively high; also, excessive loss of the desired gases (hydrogen, carbon monoxide, hydrocarbon, or nitrogen) occurs owing to their solubility in water. Water, on the other hand, is regenerated simply by depressurizing, whereas amine and carbonate require large amounts of steam for regeneration.

In processes for manufacturing synthesis gas for the Fischer-Tropsch synthesis now being developed by the Federal Bureau of Mines (*3*) and others, coal, oxygen, and steam are reacted under pressures of 300 to 500 lb./sq.in. gauge. This procedure is more economical than gasification at atmospheric pressure because the gas need not be compressed for the synthesis step, which occurs at the same pressures, and smaller lines and equipment may be used. Amine systems can be operated with greater efficiency at the elevated pressures, but the absorption capacity and steam savings are only slightly greater than at atmospheric pressure. Of considerable importance to operation at elevated pressure, however, is the greatly reduced amine losses by vaporization from the absorber.

To take full advantage of the elevated temperature and pressure at which the impure gases are available, the use of hot, concentrated alkaline solutions under pressure was investigated as a possible means of decreasing the cost of removing carbon dioxide from synthesis gas. In this system the differential (driving force) between the partial pressure of carbon dioxide in the gas and its equilibrium pressure above the solution was believed to be sufficient for absorption to be accomplished without the conventional lowering of temperature. Contrary to usual practice, absorption would then be possible at about the same temperature as regeneration. Potassium carbonate appeared to be suitable for hot absorption because of the greater solubility of the bicarbonate when compared with sodium bicarbonate. Because the carbonate-bicarbonate solution remains hot at all times, the more concentrated solutions can be used without danger of precipitating the bicarbonate. The reaction that occurs during absorption is

$$K_2CO_3 + CO_2 + H_2O \rightleftarrows 2\,KHCO_3$$

Temperatures close to 100° F. favor nearly complete conversion of carbonate to bicarbonate, whereas boiling temperatures shift the equilibrium to the left.

This study included investigation of precipitation from concentrated potassium carbonate-bicarbonate solutions, of equilibrium partial pressures of carbon dioxide over such solutions, and of pilot

plant tests. Only the relevant portion of the equilibrium data is given in this report; complete data will be published later.

Carbon Dioxide Removal by Amine Solutions

Figure 1 is a schematic flow sheet of a typical monoethanolamine plant. Variation in equipment arrangement and temperature is possible, depending on operating conditions, but the following will serve as an illustration.

Cooled amine at 100° F. enters the absorber, which is operated at 300 lb./sq.in. gauge. The heat of reaction of amine with carbon dioxide causes a temperature rise of 70° F., resulting in an exit temperature of 170° F. The depressurized, spent (rich) amine enters the top of the regenerator at 215° F. and passes through the heat exchanger countercurrent to fresh amine. In the regenerator, amine, passing downward countercurrent to hot stripping steam, is heated from 215° F. to its boiling temperature, 270° F. The regenerated (lean) solution is then passed through the heat exchanger and pumped through the water cooler to the absorber.

The steam input to the regenerator provides the heat necessary for decomposition of the amine-carbon dioxide complex. This heat, which can be calculated from the temperature rise of 70° F. in the absorber, is equivalent to about 86 B.t.u./cu.ft. of carbon dioxide absorbed. In the regenerator the decomposition of the amine–carbon dioxide complex is endothermic and requires a quantity of heat equal to that liberated in the absorber. In a typical plant, 1 gal. of 25% monoethanolamine absorbs about 6 cu.ft. of carbon dioxide/gal. of solution and requires about 1.5 lb. of 150 lb./sq.in. gauge steam for regeneration. (These amounts can be varied slightly but will serve for illustration.) Since the density of the solution is 8.3 lb./gal. and its specific heat is 0.9, the heat liberated by the reaction is

$Q_B = (8.3)(70)(0.9) = 522$ B.t.u./gal., equivalent to 0.61 lb. of 150 lb./sq.in. gauge steam.

A second need for steam results from the inefficiency of heat exchange and is calculated from the approach temperature of 55° F., which is the difference between the temperatures of the amine solution entering the regenerator and of the regenerated amine. This quantity of heat is

$Q_A = (8.3)(55)(0.9) = 411$ B.t.u./gal., equivalent to 0.48 lb. of 150 lb./sq.in. gauge steam.

$Q_A + Q_B = 933$ B.t.u./gal., requiring 1.09 lb. of 150 lb./sq.in. gauge steam.

A third steam requirement, for stripping, is the difference between the total amount of steam needed, 1.5 lb., and that corresponding to $Q_A + Q_B$, 1.09 lb., or 0.41 lb. Of the total steam, 40.6% is needed for chemical reaction, 32.0% for make-up heat, and only 27.4% for stripping. While this illustration is oversimplified, inasmuch as some of the heating steam is also effective as stripping steam, it serves to indicate the relative magnitudes of the quantities of steam involved.

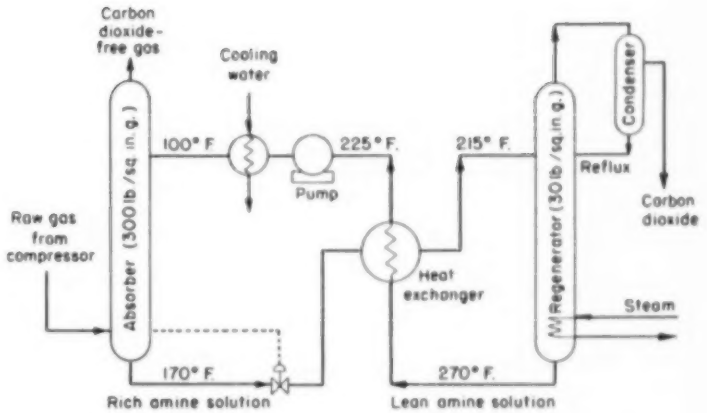


Fig. 1. Simplified flow sheet for carbon dioxide removal by amine absorption.

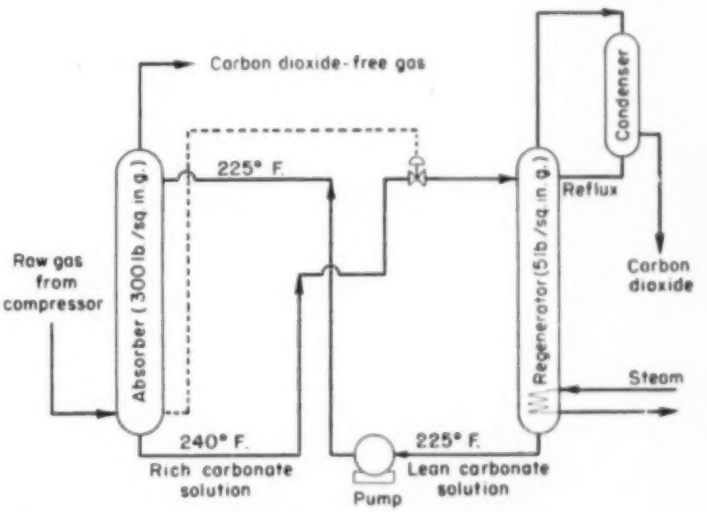


Fig. 2. Simplified flow sheet for carbon dioxide removal by hot carbonate solution.

Carbon Dioxide Removal by Hot Carbonate Solutions

Absorption of carbon dioxide under pressure by a relatively hot solution close to its boiling point has definite advantages. Heat exchange between hot and cold streams can be eliminated, and partial regeneration can be effected by flashing during pressure reduction. Figure 2 is a flow sheet for this process. The solution of potassium carbonate absorbs at the temperatures at which it is regenerated. Theoretically, 12 cu.ft. of carbon dioxide can be absorbed by 1 gal. of 40% potassium carbonate solution, if complete conversion of carbonate to bicarbonate is assumed. Under actual operating conditions, about 4 cu.ft. of gas is absorbed/gal. with a heat of reaction about 32 B.t.u./cu.ft. of carbon dioxide absorbed, resulting in a temperature rise from 225° to 240° F. in the absorber. The rich carbonate solution is depressurized immediately before stripping. Dissolved carbon dioxide and some steam are thus flashed from the solution, but the rest of the carbon dioxide is stripped by steam generated at the bottom of the column. The lean carbonate solution leaves the regenerator at 225° F. (the boiling point at the 5 lb./sq.in. gauge regenerator pressure) and is pumped to the absorber.

Because the heat evolved during absorption in potassium carbonate is only 37% of that in amine solutions, the temperature rise is much less. Flashing of carbon dioxide and steam in the regenerator cools the solution again. If

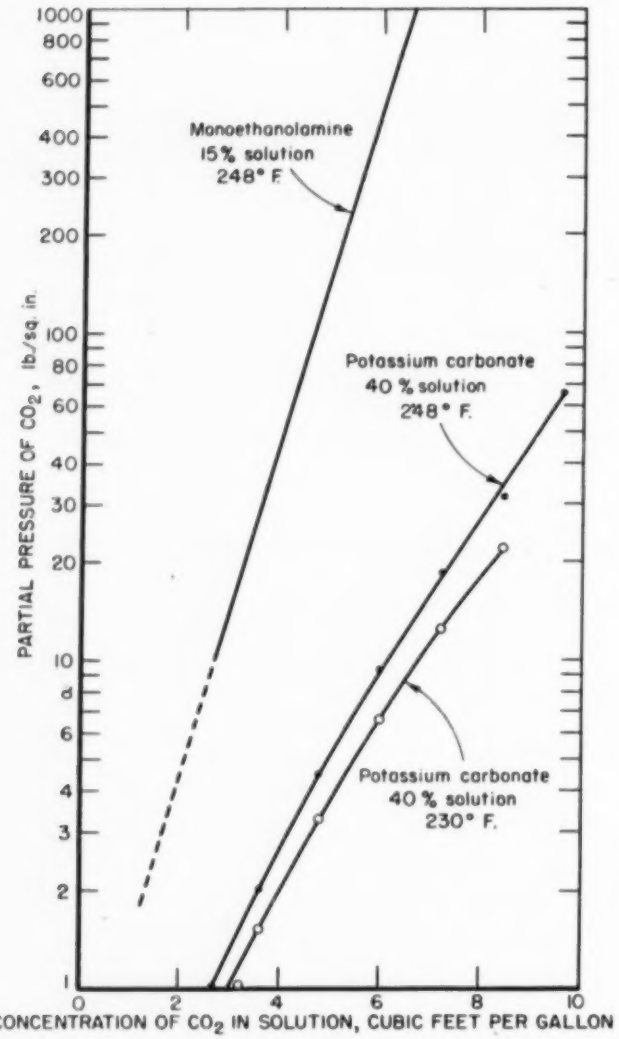


Fig. 3. Equilibrium pressures of carbon dioxide over monoethanolamine and potassium carbonate solutions.

only carbon dioxide were removed, the heat of reaction would be completely recovered; however flashing of steam entails loss of part of the heat of reaction. Steam is therefore required only for stripping and for replacing of flashed steam; heat loss in a heat exchanger is avoided. When the gas to be scrubbed is under pressure at elevated temperature and saturated with water vapor, it need be cooled to only about the atmospheric boiling point of the carbonate solution (rather than to around 100° F. as required for amine scrubbing); thus heat and cooling water are conserved.

Equilibrium and Solubility Studies

Figure 3 shows equilibrium partial pressure at 248° and 230° F. of carbon dioxide above 40% aqueous potassium carbonate as a function of concentration of carbon dioxide in the original carbonate solution. The data are compared with those obtained for a 15% monoethanolamine solution by Reed and Wood (*4*). Even at as high a temperature as 248° F., the partial pressure of carbon dioxide is quite low when the carbon dioxide content of the solution is low. For example, at 300 lb./sq.in. gauge and 230° F., the carbon dioxide content of a gas in equilibrium with the liquid is less than 1.0% (3 lb./sq.in.) if that of the liquid is about 4.6 cu.ft./gal. Lower concentrations of carbon dioxide in the purified gas could be obtained by more complete regeneration of the solution. Under actual operating conditions, the equilibrium curves are more nearly vertical because of the heat of reaction, and the absorptive capacity of the liquid for a given partial pressure of carbon dioxide in the gas is reduced. Hot potassium carbonate is preferable, therefore, to hot amine because of the smaller heat of reaction of carbon dioxide with the carbonate solution and the smaller slope of the equilibrium curves.

Solubility relations in the system potassium carbonate–bicarbonate were studied to determine operable ranges of temperature and concentrations in which no precipitation would occur. A schematic diagram of the system used for the solubility study is given in Figure 4. Potassium bicarbonate (99.7% purity) and water were charged to the reaction vessel, a high-pressure sight gauge. The vessel was provided with a magnetically driven stirrer designed to eliminate a stuffing box and possible leaks. The whole unit was submerged in an oil bath contained in a glass bell jar so that the solution might be observed at all times. Provision was made for evacuating the system after it was charged and for bleeding a metered amount of carbon dioxide after each reading.

When precipitation occurred from the carbonate–bicarbonate solutions, temperature readings were taken by a thermocouple located at the bottom of the transparent gauge. A workable range of potassium carbonate concentration (no precipitation) and maximum conversion to potassium bicarbonate were established by heating and stirring predetermined amounts of potassium bicarbonate and water until all crystals had been dissolved, then slowly lowering the temperature until the solids reappeared. A measured quantity of carbon dioxide was then bled from the system to lower the bicarbonate content by a desired amount, and the precipitation temperature was observed for the new mixture. This process was repeated several times until the rate of evolution of carbon dioxide was so slow that it was impractical to lower the bicarbonate content further. Water lost with the gas was replaced by admitting enough water to restore the original level. To prevent errors from supercooling, check runs were made, including a few in the opposite direction; that is, starting with a precipitate and raising the temperature until the solids dissolved.

The percentage of conversion to bicarbonate was determined from the amount of carbon dioxide bled off and the residual carbon dioxide in the vapor space above the liquid. The latter quantity of carbon dioxide was calculated from the measured system pressure, partial pressure of the water, and the gas space above the liquid.

Results of the solubility study are shown graphically in Figure 5. Equivalent potassium carbonate concentrations (that concentration if all potassium were present as carbonate) of 40, 50, and 60% were used with conversions to bicarbonate ranging from 97 to 15%. For each concentration the temperature of pre-

cipitation decreased as the percentage of bicarbonate became lower. This is to be expected since the solubility of potassium bicarbonate is much less than that of the carbonate.

From Figure 5 it is apparent that use of a 60% solution is prohibitive because at 245° F., near its normal boiling point, precipitation occurs at a bicarbonate conversion of only about 35%. Similarly, the 50% solution is not useful because at its normal boiling point of about 235° F. precipitation takes place when the bicarbonate conversion exceeds 48%. On the other hand, with a 40% solution there is no danger of precipitation at 225° F. until 90% of the carbonate is converted to the bicarbonate. In a continuous countercurrent absorption process, the spent solution (greatest bicarbonate concentration) is at a higher temperature than its normal boiling point. Thus, a 45% equivalent concentration of potassium carbonate can be used without the occurrence of precipitation, especially if the conversion to bicarbonate does not exceed 80%.

Pilot Plant Investigation

EQUIPMENT

Figure 6 is a schematic diagram of the pilot plant; Figure 7 is a view of the plant. The absorber, constructed of 4-in. diam., schedule 80 steel pipe, was packed with 0.5-in. Raschig rings to a depth of about 9 ft., giving a packed volume of 0.72 cu.ft. To approach adiabatic conditions, the upper and lower halves of the absorber were provided with separate insulated steam jackets, which were maintained at the average temperature of the liquid inside the absorber. To make certain of essentially adiabatic conditions at critical points in the system, test runs were made with hot water and inert gas; these showed that heat flow from or to the system was negligible. Thermocouples were located at the bottom, center, and top of the interior of the absorber and also in the two steam jackets for determining the temperature profile. A differential pressure gauge across the column gave warning of plugging or flooding difficulties.

The regenerator was constructed of 6-in. diam., schedule 40 carbon-steel pipe and contained 0.95 cu.ft. of 0.5-in. Raschig ring packing, the packing height being 4.75 ft. The amount of steam supplied to the regenerator was determined by weighing the condensate removed from the trap of the steam jacket of the reboiler. Temperatures of the entering and leaving solution were measured.

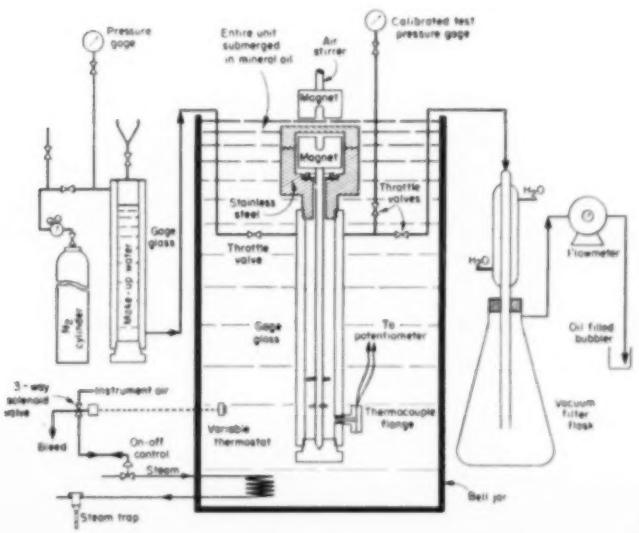
The entire system was adequately insulated and heated to minimize heat losses and to prevent the solution from cooling to a temperature where precipitation might occur. In each test regenerated and spent carbonate samples were collected and analyzed for carbonate and bicarbonate content. To make sure that these samples were representative, they were taken at system temperature in a small pressure cylinder half-filled with distilled water so that no precipitation occurred on cooling to room temperature. The carbon dioxide contents of the feed, scrubbed, regenerated, and flashed gases, were determined by Orsat analyses.

Method of Operation

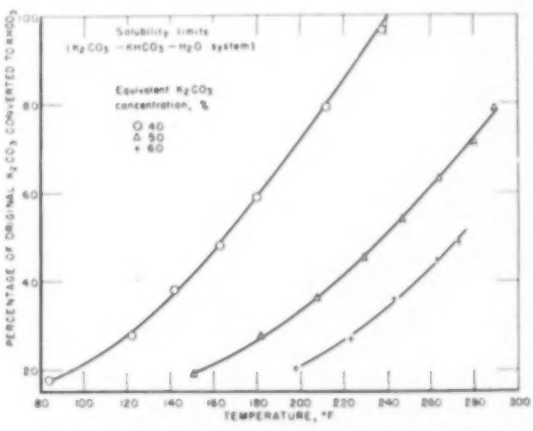
Operation involved continuous countercurrent absorption of carbon dioxide from inert gas by hot, concentrated aqueous potassium carbonate. Compressed inert gas at 300 lb./sq.in. gauge pressure, preferably hot and saturated with water vapor, at the temperature of the entering carbonate solution, was fed into the bottom of the absorber, countercurrent to the flow of carbonate.

The scrubbed gas flowing from the top of the absorber was reduced to atmospheric pressure, metered, and sampled. Since the absorber was adiabatic and the feed gas was preheated, the spent solution leaving the absorber was hotter than the entering solution by an amount equivalent to the exothermic heat of absorption. The hot, spent carbonate was depressurized in a flash drum, where part of the carbon dioxide and some steam were flashed, usually cooling the solution to slightly below the boiling temperature in the regenerator reboiler. It was possible to separate and measure the flashed steam and carbon dioxide or to bypass the flash drum entirely. For cold absorption runs the flash drum was bypassed, and the spent solution was sent directly to the top of the regenerator. To remove the rest of the absorbed carbon dioxide, the solution was stripped in the regenerator by steam generated in the reboiler by indirect steam heating. Since the steam–carbon dioxide ratio in the flashed gas usually was higher than in that leaving the top of the regenerator, the stream could be sent into the packed section of the regenerator column for stripping to reduce the steam requirements of the reboiler.

The regenerated carbonate at its boiling point was returned from the reboiler to the top of the absorber at a pressure of 300 lb./sq.in. gauge by a diaphragm pump, the flow rate of the carbonate solution being measured by an orifice meter. Steam and carbon dioxide evolved during regeneration flowed to an overhead condenser from which the condensate was returned to the column while the carbon dioxide was metered and sampled. Measuring the flow rate and temperature rise of the condenser cooling water determined the amount of overhead steam (mostly stripping steam) from the regenerator.



◀ Fig. 4. Equipment for solubility studies.



▲ Fig. 5. Effect of temperature on the solubility of K_2CO_3 plus $KHCO_3$ in aqueous solution.

Table 1.—Pilot Plant Data for

	SERIES I									
Run No.	1	2	3A	4A	5A	6A	6B	7A	7B	8
Scrubbing solution	30% MEA	30% MEA	30% MEA	30% MEA	13% K_2CO_3	40% K_2CO_3	40% K_2CO_3	40% K_2CO_3	40% K_2CO_3	40% K_2CO_3
Type of absorption	Cold	Cold	Hot	Hot	Cold	Hot	Hot	Hot	Hot	Hot
1. Absorber										
Feed gas rate, std.cu.ft./hr.	511.8	500.0	519.6	508.5	501.1	494.3	512.6	486.4	491.7	473.2
Liquid mass velocity, lb./(hr.)(sq.ft.)	2880	2880	3260	3260	3630	3750	3770	4430	4430	3690
Temp. of feed gas, °F.	70	70	70	70	70	70	70	70	70	242
Temp. of top liquid and exit gas, °F.	95	99.5	239	253	104	244	259	246	267	241
Temp. of bottom liquid, °F.	130	139.2	239	246	110	243	245	243	259	254
Total pressure, lb./sq.in. gauge	300	300	301	300	300	303	303	303	303	303
Equil. pressure of CO_2 at top, lb./sq.in.	0	0	5.0	7.0	0.2	2.0	2.8	1.9		
Partial pressure of water vapor, lb./sq.in.	.....	.....	.....	.....	.....	20.1	26.3	21.3		
Partial pressure of CO_2, lb./sq.in.	39.3	37.8	62.1	69.3	59.6	48.3	59.0	38.2	No	No
Top ΔP, atm.	2.68	2.57	3.88	4.24	4.04	3.15	3.82	2.47	Liquid	Spent
Equil. pressure of CO_2 at bottom, lb./sq.in.	2.6	6.7	38.0	37.0	10.6	11.0	13.0	8.8	Samples	Liquid
Partial pressure of water vapor, lb./sq.in.	.....	.....	.....	.....	.....	17.2	15.7	16.8		
Partial pressure of CO_2, lb./sq.in.	86.8	90.6	83.1	90.0	85.7	83.0	90.9	84.8		Samples
Bottom ΔP, atm.	5.73	5.70	3.07	3.60	5.11	4.90	5.30	5.16		
Column ln (mean ΔP), atm.	4.00	3.95	3.47	3.92	4.58	3.99	4.54	3.66		
*K_Ga, lb. moles/(hr.)(cu.ft.)(atm.)	0.083	0.098	0.061	0.048	0.046	0.062	0.063	0.085		
2. Flash drum										
Temp. of entering liquid, °F.	by-passed	by-passed	242	246	by-passed	243	245	240	262	255
Total pressure, lb./sq.in. gauge	.....	.....	10	21.5	.....	10	20	12	21.5	10
Flashed gas, std. cu.ft./hr.	.....	.....	13.0	.....	.....	.....	.....	29.8	27.0	
3. Regenerator										
Temp. of liquid at top, °F.	201	234	220	231	205	243	232	223	243	225
Temp. of liquid at bottom, °F.	235	253	239	255	241	243	262	246	268	241
Pressure, lb./sq.in. gauge	10	20	10	20	10	10	20	10	20	10
4. CO_2 concentrations, %										
Feed gas to absorber	27.6	28.8	27.2	28.6	28.2	27.7	30.3	28.1	28.0	27.5
Scrubbed gas from absorber	12.5	12.0	20.3	22.0	19.6	16.3	20.3	12.9	12.8	15.5
Regenerated gas	98.5	98.5	98.7	94.9	96.5	95.9	98.5	96.7	96.7	98.9
Flashed gas	.....	.....	.....	.....	.....	.....	.....	93.7	93.7	
Volume CO_2 scrubbed, std.cu.ft./hr.	86.6	100.5	55.0	48.7	55.0	61.1	74.1	80.3	86.0	72.4
Std.cu.ft./hr. CO_2 absorbed/gal.	3.27	3.79	1.83	1.63	1.65	2.53	2.90	2.67	2.87	2.89
5. Liquid compositions										
Regenerated solution: ratio $K_2CO_3/KHCO_3$	.....	.....	.....	.....	.972	1.51	1.44	1.58	.....	1.22
st.cu.ft. CO_2/gal.	4.0	4.0	2.0	2.0	1.27	3.57	3.82	3.70	.....	4.20
Spent solution: ratio $K_2CO_3/KHCO_3$	.....	.....	.....	.....	.032	.565	.521	.652		
st.cu.ft. CO_2/gal.	7.3	7.8	3.8	3.6	2.91	5.92	6.67	5.10		
CO_2 absorbed from gas, lb. moles/hr.	0.241	0.281	0.153	0.135	0.153	0.179	0.207	0.223	0.239	0.202
CO_2 picked up by liquid, lb. moles/hr.	.....	.....	.....	.....	0.154	0.179	0.201	0.214	.....	.....
Regeneration efficiency, std.cu.ft. CO_2/lb. of steam	4.6	4.7	5.9	5.7	2.63	7.9	5.7	7.3	5.8	12.1
std.cu.ft. CO_2/lb. of steam (calc'd for hot feed gas)	.....	.....	9.8	12.3	.....	16.2	9.4	11.6	8.9	

K_Ga = over-all transfer coefficient

SERIES II

8A	8B	1B	2A-1	2B	3A-1	3A-2	3C-1	3C-2	4A-1	4A-2	4B	5A
40% K_2CO_3 Hot	40% K_2CO_3 Hot	30% MEA Cold	40% K_2CO_3 Hot	40% K_2CO_3 Hot	40% K_2CO_3 Hot	40% K_2CO_3 Hot	40% K_2CO_3 Hot	40% K_2CO_3 Hot	40% K_2CO_3 Hot	40% K_2CO_3 Hot	40% K_2CO_3 Hot	40% K_2CO_3 Hot
501.6	500.1	508.9	497.3	450.9	462.3	455.8	450.7	467.6	467.2	468.5	450.9	240.9
3240 260	3870 263	1300 74	2130 238	2535 246	3060 246	3000 266	2260 236	2180 242	3600 262	4850 180	3025 246	3580 230
262	264	90	250	239	231	240	230	226	236	239	235	234
274	277	153	252	243	248	250	242	230	242	237	246	241
303	303	300	303	305	308	308	308	309	313	309	308	300
2.4	2.5	0	3.0	8.6	5.9	7.4	9.2	5.9	7.9	8.5	7.8	7.3
28.2	29.4	0.7	21.6	17.8	15.1	18.1	14.3	13.7	16.4	18.0	16.4	16.1
48.6 3.14	36.0 2.28	3.15 0.214	5.64 0.180	15.4 0.463	10.2 0.292	8.8 0.095	21.6 0.844	17.7 0.802	11.6 0.248	9.2 0.048	11.0 0.219	6.9 (−0.027)
28.0	40.0	15.4	18.0	23.5	22.3	28.0	26.5	20.8	24.0	19.5	28.0	16.5
20.1	20.9	.....	18.0	15.5	17.4	17.4	13.7	13.0	13.9	15.5	17.0	17.8
86.0 3.95	83.8 2.98	34.2 0.272	33.6 1.061	28.5 0.340	29.9 0.517	33.9 0.401	35.1 0.585	35.4 0.993	34.3 0.700	28.3 0.600	33.6 0.381	33.1 1.130
3.55	2.63	0.590	0.503	0.402	0.408	0.251	0.715	0.897	0.438	0.220	0.335	0.367
0.071	0.120	0.337	0.342	0.253	0.303	0.559	0.114	0.119	0.323	0.663	0.421	0.241
271	276	by-passed	255	241	241	247	239	237	247	248	248	244
20	21.5	.....	10	10	10	10	12	12	12	12	12	12
.....	33.0	.....	.....	.....	.....	.....	13.4	18.1	21.0	22.7	26.7	14.7
241	244	212	232	224	228	228	223	223	229	230	229	230
262 20	264 20	246 10	248 10	237 10	243 10	241 10	230 10	231 10	239 10	239 10	232 10	234 10
28.9	28.3	10.9	11.2	9.4	9.8	11.1	11.4	11.4	11.0	9.2	11.0	11.2
16.8 98.7	12.5 96.9 95.0	1.0 98.5	1.9 98.0	5.1 97.9	3.3 98.6	2.9 98.3	7.0 94.5 85.9	5.7 96.3 87.6	3.7 97.9 85.8	3.0 97.6 88.9	3.6 96.3 92.6	2.4 94.6 90.0
65.5	82.1	51.8	44.4	26.3	31.9	36.2	21.1	27.6	36.5	37.8	36.4	23.9
2.98	3.13	4.31	3.01	1.48	1.48	1.70	1.34	1.78	1.43	1.09	1.50	0.90
1.64 3.39	1.62 3.11	..... 3.2	1.27 3.7	0.615 5.16	0.709 4.72	0.691 4.81	0.541 5.85	0.665 4.52	0.629 4.92	0.611 4.92	0.616 4.83	0.627 4.83
.529 6.18	.428 5.52	..... 7.80	0.470 6.10	0.395 6.66	0.375 6.25	0.329 6.48	0.294 7.01	0.291 6.50	0.318 6.22	0.341 5.85	0.298 6.22	0.406 5.57
0.183	0.228	0.144	0.124	0.073	0.089	0.101	0.059	0.077	0.102	0.105	0.102	0.064
0.186	0.239	.....	0.106	0.073	0.087	0.101	0.060	0.078	0.103	0.118	0.102	0.067
9.8	8.4	2.77	6.50	11.05	10.10	10.10	8.33	12.40	8.28	7.33	7.24	8.23

Experimental Results

Table 1 shows typical results from two series of tests, one with gas containing 26 to 30% CO_2, the other with gas containing 9 to 11% CO_2. The data include flow rates of liquid and gas; temperatures and pressures in the absorber, flash drum, and regenerator; concentration of carbon dioxide in the gas streams; carbonate–bicarbonate ratios in the regenerated and spent solutions; equilibrium and partial pressures of gaseous carbon dioxide; and over-all transfer coefficients.

FIRST SERIES

Feed gas flowed at about 500 std. (32° F., 14.7 lb./sq.in.) cu.ft./hr. and liquid at 22 to 30 gal./hr. [3200 to 4400 lb./(hr.)(sq.ft.)] in the first series of tests. Initially, cold and hot absorption with 30% monoethanolamine was investigated in runs 1 to 4A.

Runs 1 and 2 were cold absorption tests at regeneration pressures of 10 and 20 lb./sq.in. gauge respectively. During these runs the flash drum was bypassed. Because the packed section in the absorber was only 9 ft. high, the scrubbed gas still contained about 12% CO_2 in both runs, and only 3.3 to 3.8 cu.ft. of carbon dioxide was absorbed/gal. Commercially, 35- to 50-ft. columns result in absorption of 4 to 6 cu.ft. of carbon dioxide/gal. and a considerably lower content of carbon dioxide in the scrubbed gas.

In runs 3A and 4A the same solution was used hot under otherwise identical conditions. The amount of absorption per gallon dropped sharply to about 1.6 to 1.8 cu.ft. because the back pressure of carbon dioxide from hot amine is quite high. However, the efficiency of regeneration was improved from 4.7 cu.ft. of carbon dioxide/lb. of steam for the cold runs to 5.8 for the hot runs.

Upon deducting the sensible and latent heats needed for heating the gas to the temperature at the top of the absorber and saturating it with water vapor, one obtains regeneration efficiencies of 9.8 (run 3A) and 12.3 (run 4A) cu.ft. of carbon dioxide/lb. of steam. (The regeneration-efficiency figures for cold absorption runs were corrected to simulate a 40° F. temperature difference between the spent solution entering the regenerator and the solution in the reboiler.) These figures are a measure of the steam consumption for purifying gas that is at the same temperature as the absorption liquid and is saturated with water vapor. Complete liquid analyses were not obtained for these tests, but approximate values of over-all transfer coefficients (K_Ga) of 0.05 to 0.1 lb. mole/(hr.)(cu.ft.)(atm.) were determined by calculating the carbon dioxide content of the spent amine by weight balances.

Cold absorption with approximately 15% aqueous potassium carbonate was carried out in experiment 5A. The concentration of carbonate is restricted at this temperature because of the limited solubility of potassium bicarbonate. Only about 1.65 cu.ft. of carbon dioxide was absorbed/gal. of solution, and the regeneration efficiency was fairly low (2.63 cu.ft. of carbon dioxide/lb. of steam). The low transfer coefficient [0.046 lb. mole/(hr.)(cu.ft.)(atm.)] agrees with that obtained under similar conditions by Comstock and Dodge (*1*).

Hot carbonate absorption was investigated in the remaining experiments of this series. In runs 6 and 7 the feed gas was cold (room temperature). The gases flashed on reduction of pressure were fed into the regenerator column in tests 6A and 6B, which were conducted at regenerator pressures of 10 and 20 lb./sq.in. gauge pressure respectively. Tests 7A and 7B corresponded closely to 6A and 6B except that the flashed gases were not fed into the regenerator but instead were sampled and metered. In tests 7A and 7B the carbon dioxide content of the scrubbed gas was about 13% compared with 16.3 and 20.3% in runs 6A and 6B. This reduction in concentration of carbon dioxide appears to be due to the greater mass velocity of liquid, 4430 compared with 3750 lb./(hr.)(sq.ft.). About the same pick-up of carbon dioxide per gallon of carbonate was observed in corresponding tests, 2.5 to 2.6 cu.ft./gal. for regeneration at 10 lb./sq.in. gauge and 2.9 cu.ft./gal. for regeneration at 20 lb./sq.in. gauge. The temperature of the solution at the bottom of the absorber was lower than that at the top because the energy required to heat and saturate the entering gas was greater than the heat of reaction. The transfer coefficient values for the two runs were low, ranging from 0.062 to 0.085 lb. mole/(hr.)(cu.ft.)(atm.). The experimental values for regeneration efficiency in tests 6A and 7A were 7.9 and 7.3 cu.ft. of carbon dioxide/lb. of steam, compared with calculated values of 16.2 and 11.6 cu.ft. of carbon dioxide/lb. of steam if the gas had been preheated and saturated with water vapor. An appreciable improvement in steam economy resulted from feeding to the regenerator column the gases obtained by flashing at 10 lb./sq.in. gauge pressure. However, such was not the case for regeneration at 20 lb./sq.in. gauge (tests 6B and 7B), for which efficiencies of 5.7 and 5.8 were measured and 9.4 and 8.9 were calculated. Approximately one-third of the absorbed carbon dioxide was flashed in both cases, the remainder being stripped from solution.

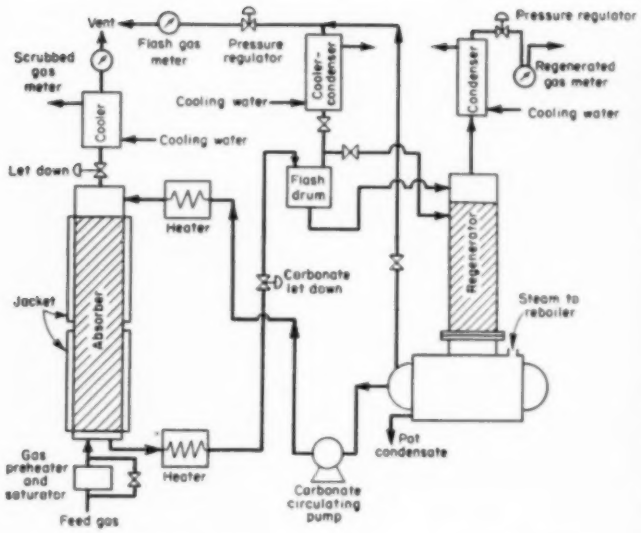
A preheated, saturated feed gas was used in run 8 so that the preceding calculated values of regeneration efficiency would be measured directly. During tests 8 and 8A, operated at regenerator pressures of 10 and 20 lb./sq.in. gauge, respectively, the flashed gases were fed into the regenerator column. Test 8B was similar to 8A except that the flashed gases were removed from the system. In all of these experiments the expected rise in temperature of the solution due to the heat of reaction was observed. The regeneration efficiency in runs 8 and 8A were 12.1 and 9.8 cu.ft. of carbon dioxide/lb. of steam at 10 and 20 lb./sq.in. gauge regenerator pressures respectively.

SECOND SERIES

In the second series of runs a preheated, saturated feed gas was used in all but the first test, which was carried out with cold 30% monoethanolamine. A gas containing only 9 to 11% of carbon dioxide was fed to the absorber to determine steam consumption figures and carbon dioxide carrying capacity and to obtain transfer coefficients under these conditions. The regeneration pressure was 10 lb./sq.in. gauge in all tests. Approximately the same gas flow was used in these runs as in the earlier series, except for run 5A, in which the flow rate was halved. The liquid flow rate was varied over a wide range.

During cold absorption with amine (run 1B), the carbon dioxide content of the scrubbed gas was reduced to 1% at a liquid flow of 12 gal./hr. (1300 lb./(hr.)(sq.ft.) mass velocity), and 4.3 cu. ft. of carbon dioxide was absorbed/gal. of solution. The regeneration efficiency was 2.77 cu.ft. of carbon dioxide/lb. of steam; this is lower than the usual commercial efficiency and is probably due to the shortness of the columns. An appreciably higher transfer coefficient (0.337) was observed than in the first series of amine runs.

Hot carbonate scrubbing was used in runs 2 to 5 at liquid flows of 14.8 to 34.8 gal./hr. [mass velocities of 2130 to 4850 lb./(hr.)(sq.ft.)]. During tests 2A-1, 2B, 3A-1, 3A-2, and 5A, the flashed gas was sent to the regenerator, whereas in tests 3C-1, 3C-2, 4A-1, 4A-2, and 4B, the flashed gases were removed, metered, and sampled. The carbon dioxide content of the scrubbed gas varied from 1.9 to 7.0%, depending upon the degree of regeneration of the carbonate, the liquid rate, and variations in the carbon dioxide content of the feed gas. In tests subsequent to run 2A-1, the carbonate-bicarbonate ratios of the regenerated



▲ Fig. 6. Schematic diagram of pilot plant for hot carbonate scrubbing.

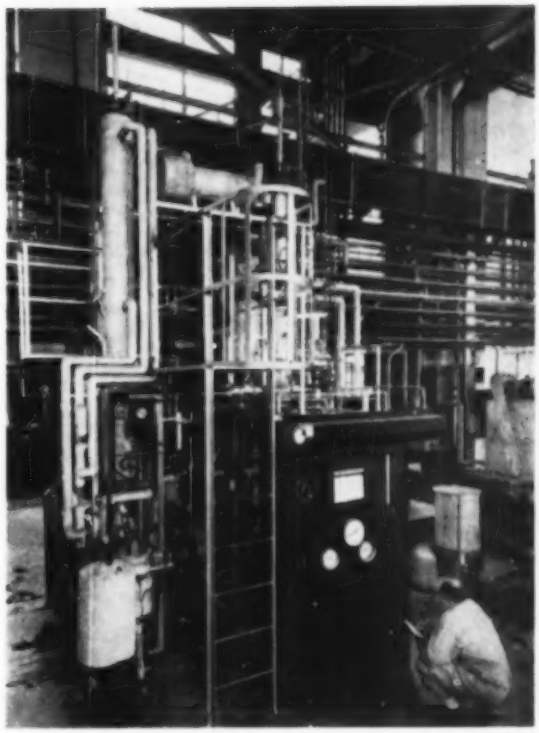


Fig. 7. View of pilot plant. ►

liquid were similar. The amount of carbon dioxide absorbed per gallon of solution ranged from about 1 to 3 cu.ft., but this could be improved by providing a greater packed height in the absorber. Regeneration efficiencies ranged from 6.5 to 12.4 cu.ft. of carbon dioxide/lb. of steam. Generally, less steam was required when the flashed gas was sent to the regenerator. Steam consumption values were corrected for small heat changes caused by variations in the temperature and for varying amounts of water vapor in the fresh and scrubbed gases. Almost 60 to 70% of the absorbed carbon dioxide was flashed in this series of tests, compared with only about one-third in the earlier runs. On the basis of cubic feet of carbon dioxide per gallon of solution, however, there was little variation in the amounts flashed. As with amine, a marked increase was found in the transfer coefficients, which varied from 0.11 to 0.66 lb. mole/(hr.)(cu.ft.)(atm.). Analyses of regenerated gas stripped from the spent solution showed only slight variations (from 95 to 99% of carbon dioxide) for all runs, but the flashed gases contained less carbon dioxide. Carbon dioxide balances in the gas streams generally agreed with the carbon dioxide pick-up in the liquid stream. Heat balances were 80 to 100% accurate.

Discussion of Results

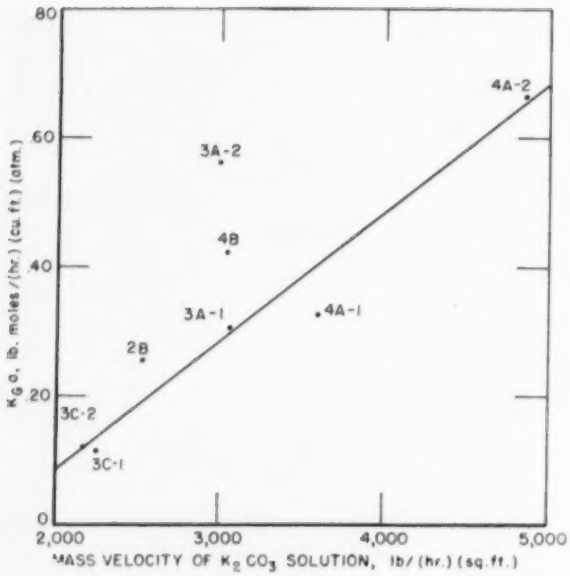
Carbon dioxide removal by a hot 40% potassium carbonate solution was conducted with a relatively low steam requirement for regeneration of the spent carbonate. The steam economy can be attributed both to the elimination of the heat required to raise the spent carbonate to the regenerating temperature and to recovery of the heat of absorption. Maximum regeneration efficiencies of from 10 to 12 cu.ft. carbon dioxide/lb. of steam were obtained when the impure gas was fed at the entering carbonate temperature and was saturated with water vapor. Partial regeneration was achieved by pressure let-down from the absorber pressure of 300 lb./sq.in. gauge to the regeneration pressure (10 or 20 lb./sq.in. gauge) with from one-third to two-thirds of the carbon dioxide being released during flashing. The regeneration of the spent solution was completed by conventional steam stripping. At certain conditions, a 50 to 60% reduction in the steam requirements for carbon dioxide removal was achieved as compared to that achieved by conventional scrubbing with amine solutions.

Within the range of liquid and gas flow rates and carbon dioxide concentrations employed in the absorber, a large partial pressure driving force existed. For the tests with a feed gas containing 28% carbon dioxide, the log mean driving force pressures were never less than 3 atm. By use of a taller absorption column, a closer approach to equilibrium could be attained with some improvement in carbon dioxide pickup and regeneration efficiency. A larger pilot plant with taller columns and other modifications is currently being used for a thorough study of the operating variables.

In the initial tests severe corrosion was encountered especially where the conversion to bicarbonate was high or where carbon dioxide and steam were released by pressure reduction. As a result of a laboratory corrosion study, a potassium dichromate concentration of 0.2% was maintained in the solution and corrosion was completely eliminated.

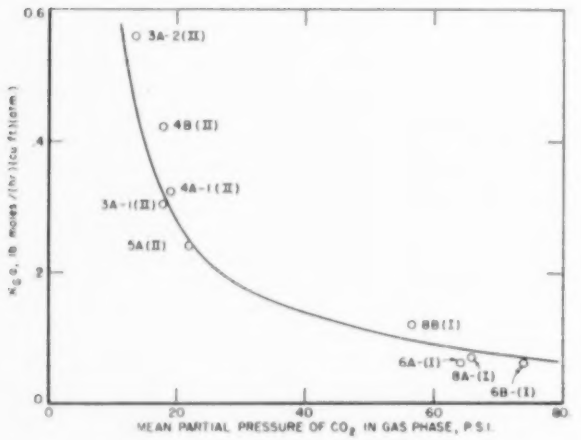
In an absorption system in which a reversible reaction in the liquid phase is carried out, the rate of transfer depends upon diffusion through the gas and liquid films and upon the rate of reaction in the liquid phase. Although it is known that diffusion and reaction in the liquid phase are controlling in this system, for ease of comparison over-all transfer coefficients were calculated from the equation

$$K_G a = \frac{N}{V \Delta P}$$



▲ Fig. 8. Variations of $K_G a$ with liquid mass velocity.

Fig. 9. Variations of $K_G a$ with the partial pressure of CO_2 in the gas phase [Mass velocity of ▼ liquid: 3,000 to 3,700 lb./(hr.)(sq.ft.)].



where

$K_G a$ = lb. mole CO_2/(hr.) (cu.ft.) (atm.) (over-all transfer coefficient)

N = lb. mole CO_2/hr. (absorption of carbon dioxide in unit time)

V = cu.ft. (packed volume), and

ΔP = atm. (mean driving force)

Similar coefficients have been determined by other investigators (*1* and *2*).

Variations of $K_G a$ with liquid flow and mean partial pressure of carbon dioxide are plotted in Figures 8 and 9, respectively. In the range of liquid flows employed, $K_G a$ increased linearly with increasing mass velocity of liquid. To eliminate the effect of a large variation of partial pressure of carbon dioxide, only values from the second series of tests were incorporated in Figure 8. In all cases there was only a slight variation in temperature of absorption and carbonate-bicarbonate ratio. For dilute carbonate solutions, Comstock and Dodge (*1*) showed that $K_G a$ increases markedly with increasing liquid rates at temperatures of 15°, 40°, and 56° C., the effect being most pronounced at the highest temperature. Because of the pronounced effect of temperature the values of $K_G a$ obtained in the present work are about three to four times as large as those reported by these investigators and others.

Figure 9 includes only data from tests in which the liquid flow was between 22 and 30 gal./hr. [3000 to 3700 lb./(hr.)(sq.ft.)]. For amine absorption Cryder and Maloney (*2*) reported a similar trend, though less pronounced than that shown in Figure 9.

Scrubbing of carbon dioxide by hot carbonate solutions appears to be commercially useful when impure gas is available (or is to be used) at elevated temperature and pressure. In such a case economy can be realized in the following ways: reduction in the amount of steam necessary for regeneration of the scrubbing agent, equipment savings by elimination of heat exchangers and coolers (these usually account for about one-third of the cost of the scrubbing plant), and large reduction of the quantity of cooling water. In addition, loss of scrubbing agent (potassium carbonate) is eliminated, and loss of amines by volatilization may be costly. For this latter reason and because of the low carbon dioxide carrying capacity of hot amine, absorption by hot amine is not attractive under such conditions. Generally, loss of gas components (carbon monoxide, hydrogen, nitrogen, hydrocarbons) by solution in hot carbonate and cold amine is negligible. The over-all transfer coefficients are also of the same order of magnitude, but 10 to 20% greater carbonate flow is required to remove as much carbon dioxide with carbonate as with cold amine.

Acknowledgment

The authors are indebted to W. P. Haynes for obtaining the equilibrium data; to Dr. M. A. Elliott, professor of mechanical engineering at Illinois Institute of Technology, for assistance in planning the investigation; to A. J. Forney, J. S. Tosh, and G. E. Johnson for pilot plant operation; and to personnel of the analytical and drafting groups for their services.

Literature Cited

1. Comstock, C. S., and B. F. Dodge, *Ind. Eng. Chem.*, **29**, 520 (1937).
2. Cryder, D. S., and J. O. Maloney, *Trans. Am. Inst. Chem. Engrs.*, **37**, 827 (1941).
3. McGee, J. P., L. D. Schmidt, J. A. Danko, and C. D. Pears, Paper presented at annual meeting *Am. Inst. Mining Met. Engrs.*, New York (Feb. 20, 1952).
4. Reed, R. M., and W. R. Wood, *Trans. Am. Inst. Chem. Engrs.*, **37**, 367 (1941).
5. Reich, G. T., *Chemical & Met. Eng.*, **38**, 136 (1931).

Presented at A.I.Ch.E. Forty-fifth annual meeting, Cleveland, Ohio.

ENGINEERS CAN WRITE BETTER

H. J. Tichy Hunter College of the City of New York

PART III

In this third article of the series Dr. Tichy guides chemical engineers in selecting words, in reducing verbiage, and in understanding the you-approach. She ends the series with a one-word formula for general improvement in writing. As in the first two articles, the approach is the practical one of using sentences such as chemical engineers write in technical articles, in reports, and in letters. Part I of the series treated the six most common sentence errors of chemical engineers; Part II demonstrated how to write more effective sentences and urged that word choice and sentence length be determined according to subject matter and reader and not according to arbitrary rules.

"Reading maketh a full man . . . and writing an exact man," said that great scientist and philosopher Sir Francis Bacon. His words, an excellent motto for any writer, apply with particular aptness to technical writers.

The author of a technical article is often of necessity a highly specialized worker and thinker; his greatest accomplishments come from attention concentrated on a tiny area of knowledge. That very narrowing of interests which leads to success in scientific theorizing and experimenting contains the danger of narrowing the specialist's viewpoints. Successful technical writing requires breadth of understanding—knowledge of the reader's needs and views, a wide stock of general words and of words in other special fields, and perception of the relationships between his subject and world knowledge and experience. Reading fills a man with this broad understanding.

Writing, particularly scientific writing, demands exactness. The artist may choose words for sound, for imaginative suggestiveness, for associations and surrounding atmosphere; but the technical writer must search painstakingly for the word that conveys his precise meaning as accurately, as explicitly, as unmistakably as numbers convey his mathematical concepts. How happily many technical writers turn to the figures and symbols with which they can express fine distinctions easily. How unhappily they struggle with words and sentences which seem many times to defy obstinately the thinker who must express concepts nicely. This frustrating struggle to give verbal expression to scientific ideas requires exact thinking, and so "writing maketh an exact man."

To write clearly a man must first think clearly. Frequently the technical writer's first problem is not one of communication but one of thinking. The majority of the common sentence errors of chemical engineers which were discussed in the first article of this series and many of the weaknesses in sentence emphasis analyzed in the second, result from muddy thinking. The need for explicit concepts is even more obvious in a study of diction. To find the right word a writer must discriminate among shades of meaning. Does he mean *adaptable, alterable, changeable, compliant, conformable, ductile, elastic, erratic, flexible, fluctuating, malleable, mobile, mutable, plastic, pliant, protean, resilient, shifting, stretchable, vacillating, variable, versatile,* or *wavering?* He may choose the wrong word because he is not sure precisely what he does mean. The man who knows exactly the thought he wishes to convey has completed at least half the work of communication.

The second part of his work is diligent search for the right words. One would expect men with scientific training to be particularly careful in selecting words. The logical thinking, mathematical accuracy, and attention to details necessary in the sciences ought to lead to logical, accurate, painstaking choice of diction; yet often the reverse is true. Too frequently technical papers written by competent engineers display incorrect, vague, ambiguous, and confusing diction. Many such errors and weaknesses are an iron curtain between reader and writer, a small number may provide a fog, and even when the errors are not serious or numerous, they can create a block in the mind of the reader to whom they give an impression of carelessness, illiteracy, or incompetence.

The fact that certain errors and weaknesses in diction are common in the writing of chemical engineers brightens the prospect for improvement. To save engineers a search in glossaries which contain many errors they may never make, the words which engineers most frequently misuse are presented here in four lists and illustrated by sentences such as engineers write in their technical articles, reports, and letters. If the writer who wishes to improve uses the four lists of common errors as suggested below, he should be able to correct and strengthen his expression quickly and easily.

Chemical engineers are trained to accuracy, to the perception of fine differences, and to precision. Men who are careful about figures ten points beyond the decimal should not find it hard to distinguish broad differences in the meanings of words; yet chemical engineers often confuse words similar in sound or appearance but widely differ-

ent in meaning. They misuse words like *economic* and *economical*, *infer* and *imply*, and *affect* and *effect*. A little time spent studying List 1, which contains similar words often confused, will eliminate mistakes frequently found in the speeches, reports, and published papers of chemical engineers. The reader should scan this list and check for future study words that he uses incorrectly.

Lists 2 and 3 contain vocabulary chemical engineers use incorrectly not because they are confused by similarities but because they see and hear the words misused. The chemical engineer uses the diction of List 2 in technical articles, reports, and accounts of conventions and meetings. The words in List 3 appear in his reports and letters. The incorrect usage illustrated in these two lists is so common that the correct forms may sound wrong to a man who does not read much besides reports and letters; therefore some engineers may need to study carefully the explanations and illustrations of the words in Lists 2 and 3.

List 4, which contains examples of wordiness and tautology, illustrates two major diction weaknesses of chemical engineers—a tendency to use unnecessary words and a tendency to repeat meaning ineffectively. They write like this—

Peter Pilot cannot help but write up reports in the nature of chemical engineering in which he has got to repeat again data he has met up with in the literature. In connection with all of this he advises that results obtained in the area at above 100° F. can be connected up with figures procured at temperatures in the area of 50° F. **(1—Wordy)**

Peter Pilot cannot help writing chemical engineering reports in which he must repeat data from the literature. He states that results obtained above 100° F. can be connected with results obtained near 50° F.

(1—Improved)

The reader who does not understand the changes made in this sentence will probably find List 4 helpful. Many of the wordy expressions in that list appear often in technical articles submitted for publication.

Few errors in style are as tiring and annoying to the reader as wordiness and vagueness. The chemical engineer who strives for effective expression will comb Lists 3 and 4 for his particular weaknesses in tautology. He will also examine his writing critically to eliminate other unnecessary words. Principal offenders in chemical engineering papers are *absolutely parallel, along the line of, first and foremost, in connection with, in the nature of, in relation to, large in size, many in number, more perfect.* Vagueness, the second major weakness, often results from the incorrect use of omnibus words. Omnibus words, general and inclusive terms, are used by chemical engineers in place of definite, specific terms. Words like *aspect, case, field, factor, important, kind, line, point, thing,* and *type* should be viewed with suspicion. In the following examples these words should be replaced:

An important factor in the field of using solar energy is the case of certain countries where cooking a kind of midday meal by the sun's rays is a possible phase in point. **(2—Weak)**

In some tropical countries solar energy may be used to cook midday meals of beans and rice. **(2—Improved)**

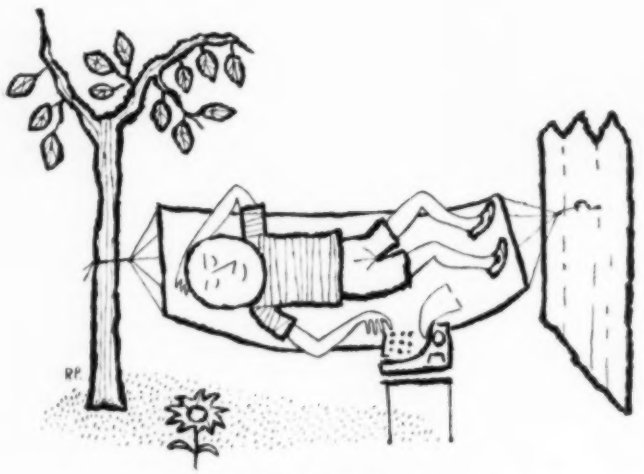
Cooking simple midday meals in tropical countries is a principal use of solar energy. **(2—Improved)**

An important factor in relation to safety precautions is first and foremost giving to workmen some kind of a clear and definite instruction along the line of not coming into the radioactive area in connection with their work. **(3—Weak)**

For safety tell workmen to avoid the radioactive area. **(3—Improved)**

Removing unnecessary verbiage is a quick, simple way to increase force and clarity. More than other writers with the possible exception of businessmen and educators, the chemical engineer uses many words to do the work of one. He *puts in an appearance;* he does not *appear.* He *starts in to write prior to*; he does not *write before.* When an editor can eliminate in a first reading a quarter of the words of a technical article, it seems to him that the engineer wrote as though he were being paid by the word to make his language as difficult and confusing as possible, and the editor must forcibly remind himself that the article is a free contribution to the enlightenment of the world.

The engineer who wishes to write better will benefit quickly from a study of the principles of good diction. Unfortunately this article, which analyzes and illustrates a number of errors in writing, does not have space for the detailed study of diction that would benefit engineers the most, but handbooks of writing do explain and illustrate in detail the principles of good word choice.



It isn't hard to write better.

As the handbooks do not always use the same terminology for the titles of sections that engineers need to consult on diction, it is worth taking time here to suggest headings. Analysis of wordiness and tautology may be found listed under *circumlocution, elimination of deadwood, prolixity, redundancy,* and *verbosity.* Engineers who use inappropriately elegant words where simple ones are better should consult sections listed under *appropriate diction, elegance, fine writing,* and *pretentious language.* Engineers who are afraid to use the same word twice should study *elegant variation.* Nearly every writer benefits from a review of material on *colloquialisms, conciseness, concrete diction, figurative language, good usage, jargon or unnecessary shoptalk, simplicity and directness, specific words, trite or threadbare diction,* and *use of the dictionary.*

The readers of this series if they are like other adults interested in writing better have probably been waiting for the subject of punctuation. It may be

hard for them to believe than an adviser on writing does not consider punctuation a *major* writing problem of engineers. Perhaps because it was a bugaboo of their student days, adults interested in writing are often worried about punctuation. Many of their punctuation problems are relatively unimportant. All of them are answered simply and clearly in standard handbooks of writing.

Chemical engineers can easily read and understand the rules and illustrations if they will give up two notions which are obstacles to their use of handbooks on writing. The first is that they can find rules for omitting punctuation. No one has had the desire or patience to list all the places in a sentence that do *not* require punctuation. Handbook writers explain as lucidly as possible where punctuation is used today. If there is no rule for including punctuation, the engineer should leave it out and not waste time looking for a rule to tell him to omit it. The engineer's second handicap in using handbooks is his conviction that they are written in a foreign language composed of words he considers impossibly difficult, like *gerund* and *participle*. This attitude is ironic in chemical engineers because of the difficulty of the jargon of their profession for the layman. Chemical engineers can read titles like "Correlation of Nitrogen-Methane Vapor-Liquid Equilibria by Equations of State," "Effect of Column Holdup and Reflux Ratio in Binary Batch Distillation," "Vapor Phase Catalytic Esterification Rates," and "Moving Bed Recycle Catalytic Cracking Correlations." How can they quail before a few grammatical terms? The attitude is not reasonable. Most handbooks have glossaries of grammatical terms, and it takes only a few minutes to use them. A good handbook will help engineers if they will give it a fair chance. A thoughtful survey of the rules so that they may quickly find the ones they want, careful reading of the rules, and examination of the illustrations will solve the punctuation problems of engineers.

The Million-Dollar Comma

Only one mark of punctuation is of sufficient importance to the chemical engineer to merit consideration in this article. The comma that indicates nonrestriction may change the meaning of a sentence as much as alterations in words and phrases may. It seems strange that the lightest mark of punctuation has in this instance such great effect. The nonrestrictive comma is a legal comma in the sense that its presence or absence in a will or tax bill, for instance, may determine the disposition of millions of dollars. In the same way ignorance of the use of that comma might conceivably be very expensive or dangerous for a chemical engineer.

Fortunately the rule for the use of the nonrestrictive comma is easy to understand and apply. A nonrestrictive adjective phrase or clause is set off by commas; a restrictive adjective modifier is not set off by punctuation. The restrictive phrase or clause limits the meaning of the word or words it modifies.

"Reading maketh a full man . . ."
—*Sir Francis Bacon*

The modifiers in dark type in the following sentences are restrictive:

All chemical engineers **who have been employed in industry for three years or more** are eligible. **(a)**

All workers **found in the radioactive area** are to be tested at once. **(b)**

Chemicals **that are approved for use** should be listed on the form. **(c)**

In sentence *a* the clause limits the subject *all chemical engineers* to those with a particular type of experience. In *b* not all workers are meant but only those found in the radioactive area. In *c* only chemicals approved for use are to be tested. In each case the modifier limits the meaning of the word or words it describes.

The modifiers in dark type in the following sentences are nonrestrictive:

Chemical engineers, **who have training in both chemistry and engineering,** should be represented on this committee. **(a)**

This section of the law applies to all workers in the area, **who should be given the proper printed forms.** **(b)**

In sentence *a* chemical engineers in general are meant, and the clause *who have training in both chemistry and engineering* merely adds information. It does not limit the meaning of the phrase *chemical engineers*. Sentence *b* means that the law applies to all workers in the area. The fact that they should be given forms is additional material that does not limit the meaning of the phrase *all workers*.

In some sentences the modifier may be either restrictive or nonrestrictive, and the presence or absence of commas changes meaning.

All workers **who have used the machine** are to be questioned. **(a)**

All workers, **who have used the machine,** are to be questioned. **(a')**

Sentence *a* means that only workers who have used the machine are to be questioned. Sentence *a'* means that all workers have used the machine and that all are to be questioned. In *a* the clause in dark type limits the number of workers; in *a'* the clause does not limit and the meaning is all workers.

Send for ambulances for all the men in the department **who have been exposed.** **(b)**

Send for ambulances for all the men in the department, **who have been exposed.** **(b')**

Sentence *b* means that not all the men have been exposed. The clause in dark type limits the men meant to those exposed. Sentence *b'* means that every man in the department has been exposed because the comma indicates that the clause in dark type does not limit the meaning of the phrase *all the men*.

Chemicals **listed first on Form C** should be ordered first. **(c)**

Chemicals, **listed first on Form C,** should be ordered first. **(c')**

In *c* the clause in dark type limits the chemicals to those listed first on Form C; only chemicals listed first on Form C should be ordered first according to this sentence. Adding commas to the sentence changes the meaning. Sentence *c'* means that all chemicals are listed first on Form C and should be ordered first.

The filters **appropriate for use in the home** are to be displayed. **(d)**

The filters, **appropriate for use in the home,** are to be displayed. **(d')**

Sentence *d* states that the filters appropriate for use in the home, which are only a part of the total number of filters, are to be displayed. Sentence *d'* means that the filters under discussion are all appropriate for use in the home and are all to be displayed.

All new employees who have been cleared are to be admitted to the laboratory. (e)

All new employees, who have been cleared, are to be admitted to the laboratory. (e')

Sentence *e* admits to the laboratory *only those new employees who have been cleared*. Sentence *e'* admits *all new employees* to the laboratory and adds the information that new employees have been cleared. A man reading *e* without knowledge of the nonrestrictive comma might admit all new employees, cleared or not. Reading *e'* carelessly, he might not know that *all* new employees had been cleared.

Those who wish to study other examples of the use of the comma that indicates nonrestriction will find good illustrative sentences in writing handbooks (*1*), but the reader must beware a tendency to simplify the rule too much. Some handbook writers speak of the nonrestrictive element as one which may be omitted from the sentence without a change in meaning, but often a restrictive element modifying a small part of a sentence may be omitted without, as far as the student can see, any marked change. The question to ask is whether the modifier limits the word or words it describes, not whether it changes the meaning of the sentence.

The You-Approach

The you-approach in writing, like punctuation, has been called to the attention of engineering students and engineers so strongly and so frequently that they have sometimes become confused. The you-approach is not the use of the pronoun *you* wherever possible. A letter in which every sentence begins with *you* is just as annoying to a reader as one in which every sentence begins with *I*. The engineer who writes in a technical article, "Substituting *y* for *t* in this equation, you solve it as follows . . . . ." evokes in many readers the response, "It's your problem, bud. *You* substitute and *you* solve." Even more annoying is the assumption of the reader's docile agreement implied in such statements as, "You will agree that the first method is superior just as soon as you read my proof." The reader answers belligerently, "Who says I will?"

Another incorrect assumption concerning the you-approach is that the writer achieves it by placing himself in the position of the reader. The trouble with this method in practice is that the writer becomes reader without changing in any way. In the first article of this series, for example, an advertising copywriter told Peter Pilot, "Brother, you can't put every idea into one type of sentence or vocabulary any more than you can put every woman into one style." The fashion writer put herself in the reader's place and wrote in terms of women's styles, but Peter Pilot is neither a woman nor a fashion expert. He understands statements that not every man can wear the same hat, that not every idea in chemical engineering can be expressed in the form of a graph, and that not every filter removes or collects every kind of dust. The full implication of the idea may escape him when the fashion writer merely puts herself in his place instead of becoming Peter Pilot. To achieve a good you-approach a writer must not merely become the reader but must take on the nature and character of his reader. If he is writing for chemical engineers, he must know enough about them and their profession to interpret in terms of chemical engineering or to use familiar material and methods of chemical engineering, such as charts and graphs, to clarify his ideas.

The true you-approach is a courteous and intelligent adjustment of subject matter and style to the reader. Many writers employ the method successfully without ever using the pronoun *you*. It is almost impossible to succeed, however, without knowing and estimating the reader or hearer. The technical writer must know, for instance, his readers' vocabularies, the extent of their understanding of technical material, their interest in technical material, their reading skills. The more he knows about his readers the easier it is to suit his writing to them.

The Magic Formula

Readers of how-to articles, whether the articles tell how to live without fear, how to build a provincial bookcase with shelves large enough for back issues of C.E.P., or how to write better, search hopefully for a formula, a single admonition or instruction that will help them to achieve the desired result with almost supernatural ease. It is a pleasure to be able to meet that desire of the reader of this article with a magic one-word formula—READ.

Not many people try to become artists without ever looking at great works of art or composers without listening to music, but many try to write without first reading. Among those who would write but not read are many engineers and engineering students. No other student howls so loudly against required reading courses as the engineering student; yet soon after he enters his profession he wants to learn to write better. His courses in literature do not seem a sufficiently direct approach to a skill that he will need in his profession; yet many direct approaches, like some of the remedial measures Peter Pilot tried, accomplish little.

From good literature a reader can acquire a feeling for words and sentence structure, a larger vocabulary, a knowledge of the organization and development of paragraphs and whole works, and an appreciation of effective style. These benefits reflect gradually in his writing. Unfortunately for the nonreader there are few other ways of acquiring this knowledge easily. Private tutoring, handbooks, exercises, writing classes, all help, but they accomplish much more if a man reads.

"Reads what?" asks practical Peter Pilot. The answer varies with the man except for the provision that what he reads should be written well. Nearly every adult recalls the titles of a number of books that he has always wanted to read. They are the easiest place to begin. It matters little to his writing whether Peter Pilot reads first *Moby Dick*, Shakespeare's sonnets, A. N. Whitehead's essays, the Bible, or *Gulliver's Travels*. If some of the books prove disappointments, Peter Pilot should drop them and turn to others on his list. He can always sample the discarded books later when his reading skill will have improved and his tastes may have changed.

Librarians can help Peter Pilot to plan a reading program. He need only explain that he is a chemical engineer reading for enjoyment and for improvement of his writing to receive useful assistance. In fact, for the modern librarian trained in reader service, Peter Pilot has all the charm and interest of a hitherto undiscovered land awaiting cultivation.

If for some reason an engineer cannot consult a librarian, he will find two inexpensive books helpful. *Good Reading* (*2*) lists a hundred significant books, presents comments and bibliography according to historical periods and literary types, and has a long consideration of particular interest to chemical engineers—the section on the humanities and sciences. *The Wonderful World of Books* (*2*) has convincing and delightful short essays on the pleasures of reading, on reading better, and on choosing books. Both volumes convey something of the adventure and magic of reading.

One word of caution is necessary because many engineers have been impressed by a need to read faster and faster and still faster until they seem determined to become whirling dervishes in the world of books. Not all books are meant to be read speedily. To read and grasp information quickly is useful. No reader should ever worry, however, about lingering over a book that brings him great ideas. The man who should worry is the one who rushes through books that are meant to be

"chewed and digested." To bolt lunch with frantic modern speed often ultimately limits the diet to milk and crackers; the mental indigestion resulting from bolting books written for careful leisurely reading may ruin a man's reading ability and joy. To read great literature at a suitable speed with pleasure, enjoyment, and understanding is to live with the immortals. Why take a quick tour through paradise when one can linger with the gods?

LIST 1

Similar Words Often Confused by Engineers

Accept, except—*Accept* means *to agree to, to believe as true, or to receive; except* means *to exclude or to leave out.*

Examples: He *accepted* the writer's conclusions. He *excepted* sulfuric acid from the list of chemicals to be purchased from the three companies.

Affect, effect—The verb *affect* means *to influence;* the verb *effect* means *to bring to pass, to accomplish. Effect* is also used as a noun meaning *result.*

Examples: Any rise in temperature *affects* storage safety. The company attempted to *effect* safe storage by insulation, air cooling, and air drying. The *effect* of additional heat must be determined by further experimentation.

All ready, already—*All ready* means *completely ready; already* means *by this time, previously.*

Examples: The materials for the experiment are *all ready.* The materials have *already* been delivered.

Continual, continuous—*Continual* means *frequent repetition, breaks in succession; continuous* means *unbroken continuity, no cessation.*

Examples: The mechanical failures caused *continual* interruptions of the flow of liquids. The new pump and improved piping resulted in a *continuous* flow of liquids.

Credible, creditable—*Credible* means *worthy of belief; creditable* means *deserving of praise.*

Examples: I find his proof *credible* because it agrees with my conclusions. His determination to complete the experiment is *creditable.*

Complement, compliment—*Complement* is *that which completes; compliment* is *praise.*

Example: The tables prepared at the university laboratory *complement* the results obtained from industrial experiments.

Definite, definitive—*Definite* means *explicit, with fixed limits; definitive* means *establishing limits, settling something finally, absolute.*

Examples: This explanation of the problems of nuclear engineering is *definite,* but it will be many years before any such statement may be termed *definitive.*

Device, devise—*Device* is *a contrivance, a machine, a trick; devise* means *to invent, to plan.*

Examples: His *device* for remote control of power is useful when materials may be radioactive. A variety of protective measures must be *devised* for the entire area of the nuclear energy experiment.

Economic, economical—The adjective *economic* is usually employed today for *management of the income, expenditures, natural resources of a government or community;* the adjective *economical* is used for *frugal, thrifty, avoiding waste.*

Examples: The new tax had wide *economic* implications. The new filter makes the operation of the unit more *economical.*

Excess, excessive—*Excess* as a noun means *superfluity;* as an adjective, it is used for *more than or above the specified amount. Excessive* is an adjective meaning *exceeding what is usual, greater than the usual amount.*

Examples: The *excess* of liquid was piped to the tank. His *excessive* clarification made his proof too long. His *excess* baggage made the trip expensive.

Infer, imply—*Infer* means *to draw a conclusion, judge from evidence; imply* means *to hint, to suggest, to insinuate.*

Examples: These figures would lead any business man to *infer* that the process is expensive. When you write to him, *imply* that the figures are too incomplete to be trustworthy.

Its, it's—*Its* is a possessive pronoun; *it's* is the contraction of *it is.*

Examples: *It's* time the committee planned *its* next meeting.

Lay, lie—Avoid confusing the transitive verb *lay, laid, laid* with the intransitive *lie, lay, lain.*

Examples: Tell him to be careful when he *lays* the explosive in the box. His logical presentation of the reasons *laid* a foundation for favorable action by the committee. He *had laid* the filter in the duct before he noticed the defect. The filler *lies* to the right of the pipe. The laboratory *lay* idle for months while the explosion was investigated. The report has *lain* on his desk for two weeks.

Leave, let—*Leave* means *to go, to depart; let* means *to permit, to allow.*

Examples: *Let* him order supplies. *Let* him work alone. *Let* us *leave* early. He will *leave* on the morning train.

Liable, likely—*Liable* indicates *probability only if the event is unpleasant; it means legally responsible. Likely* is used after *most, quite, very, etc., to mean probably.* It is also an adjective meaning *capable or credible.*

Examples: He is *liable* for the debts of the organization. Jones will very *likely* be a good chairman of admissions. He is a *likely* worker. His theory is *likely* and should be tested.

Per cent, percentage—*Per cent,* which means *by the hundred,* follows a numeral in formal writing; otherwise *percentage* should be used.

Examples: *Four per cent* of the animals were examined carefully. (Note the use of a plural verb because the *four per cent* were examined individually.) *Four per cent* of the chemical is impure. (Note the singular verb because *four per cent* is understood collectively.) A small *percentage* of the chemicals is impure. A small *percentage* of the workers are refusing the health tests for personal reasons.

Practical, practicable—*Practical* means *useful or sensible* as opposed to *theoretical; practicable* means *possible, capable of being put into practice, usable. Practicable* does not apply to persons.

Examples: The ideas he proposed for correcting mechanical flaws showed him to be a *practical* person. His ideas for repairs proved *practicable,* and he was able to continue the experiment.

Principal, principle—The adjective or noun *principal* means *chief or major;* the noun *principle* means *rule, basic law, fundamental truth, doctrine.*

Examples: The *principles* on which the experiment is based are questionable.

The *principal* reason has been stressed often.

Raise, rise—The transitive verb is *raise, raised, raised;* the intransitive is *rise, rose, risen.*

Examples: For the second part of the experiment we *raise* the temperature twenty degrees. (*raised* the temperature, *had raised* the temperature.) With increases in pressure, the temperature of the liquid *rises.* (*rose, had risen.*)

LIST 2

Words Commonly Misused by Engineers

Ability, capacity—*Ability* is the *power to perform; capacity* is the *power of receiving or holding.*

Correct: He demonstrated his *ability* to judge distances by eye when he estimated the *capacity* of the tank in a few seconds.

Aggravate—Avoid using *aggravate* for *annoy, irritate, exasperate.* It means *to intensify or make worse.*

Correct: Failure to wear protective clothing will *aggravate* the dangers for a man in the radioactive area.

Alternate, alternative—Use *alternate* for *substitution or for occurrence or performance in turn.*

Correct: The *alternate* often attended in place of the delegate. The *alternates* in the tube bank were four- and six-tube rows.

Use *alternative* for a *choice between two possibilities.* For more than two use *choice, option, preference.*

Correct: The *alternatives* are to increase precautions or to prohibit entrance to the area.

Among, between—Use *among* for references to more than two; *between* for only two.

Correct: The material is divided evenly *between* the two laboratories. Ten copies are not enough for rapid circulation *among* five hundred employees.

Amount, number—*Amount* is used for an *aggregate; number* for an *aggregate of units* which can be counted.

Correct: The *number* of ounces of uranium that the breeder requires to produce the given *amount* of plutonium is easily determined.

And—Avoid the expression *and etc.* because *etc.* means *and so forth.*

Correct: He spoke of various sources of energy —coal, tar, oil, water, sun, nuclear fission, *etc.*

Avoid using *and* after verbs that require an infinitive.

Correct: He will try *to solve* the equation (not *and solve*). Come to *inspect* our safety devices (not *and inspect*).

Apparent, evident, obvious—Anything *apparent is perceived by the senses; anything evident is proved or accepted as true;* anything *obvious is so plain it cannot be missed.*

Correct: The odor of the chemicals was *apparent.* The equation is *evident.* When the plant exploded, his mistake was *obvious.*

Appreciate—Avoid qualifying *appreciate* with unnecessary words like *highly, greatly, and very much. Appreciate means to esteem rightly, to value highly.*

Correct: I *appreciate* his kindness.

As, as if, like—*As* and *as if* are followed by clauses; *like* precedes a substantive without a verb.

Correct: He worked in the laboratory *as if he had had experience.* He works *like an experienced chemist.*

Center—Avoid *center about.*

Correct: The airplane *circled about* the target. He *centered* his attention *on* the meter. The main problem *centers in* the choice of fuel.

Fewer, less—*Fewer* is used for number; *less* for amount or degree.

Correct: The first experiment produced *fewer* by-products than we had anticipated. He used *less* sulfuric acid. *Less* pressure meant *fewer* mechanical failures.

Former, latter—*Former* refers to the *first* of *two objects; latter* to the *second* of *two objects.* When there are more than two, use *first* or *last.* It is better to repeat the word if the reference is not immediately clear.

Correct: In comparing solar energy and heat from coal, he stated that the *former* is too uncertain and the *latter* too expensive.

Fix means to *determine, to establish, to fasten.* It should not be used in formal writing for *mend, repair, adjust.*

Correct: The chairman *fixed* the time of adjournment. The mechanic will *repair* the pump.

Gotten—The form preferred today is *got.*

Correct: If we had *got* the proper chemicals in time, the stored material would not have spoiled.

Got is colloquial for *possess or must;* it is correct for *obtained.*

Colloquial: Have you *got* the report with you?

Correct: *Have* you the report with you?

Colloquial: He *has got* to write more clearly.

Correct: He *must* write more clearly.

Correct: Have you *got* from the reserve stock the chemicals you needed?

I.e.—This abbreviation for *that is* should be used only when what follows equals what precedes.

Correct: Only three are considered fissionable fuels—*i.e.*, U^{235}, Pu^{239}, and U^{233}.

Is because, is when, is where—To complete the verb *is* use a noun, noun clause, or adjective, not an adverbial construction.

Correct: His reason for transferring *is that* his wife prefers the new community (*not* is because). A critical mass *is the amount* of uranium necessary for a chain reaction (*not* is where there is).

Kind, sort—Avoid using *kind of, sort of* for *somewhat* or *rather.*

Correct: His speech was *rather* informal.

Avoid using the article *a* with *kind of* and *sort of.*

Correct: This *kind of thermometer* gives the best results (*not* this kind of a thermometer).

Last, latest—*Last* means *final, that which follows all others; latest* means *most recent.*

Correct: He always knows the *latest* theories. When Professor Green died his *last* experiment was complete.

Perfect, unique—Like *appreciate,* these words do not have degrees and cannot be compared, nor should they be qualified by words like *very.*

Unique should not be confused with *unusual, rare, odd;* it means *sole.*

Incorrect: The second test gave *more perfect* results.

Correct: The second test gave *better* results. The second test gave *perfect* results.

Proven—Use the modern past participle *proved.*

Correct: The experiments have *proved* his theory valid.

Size—Avoid using *size* for *sized.*

Correct: He asked for smaller *sized* pipes.

Errors . . . give an impression of carelessness, illiteracy, or incompetence.

Thereby, therefore—*Thereby,* an adverb, introduces phrases; *therefore,* a conjunctive adverb, introduces clauses.

Correct: He increased the pressure, *thereby placing too much strain on the old pump.* He wished to increase the pressure; *therefore he installed a new pump that would stand the strain.*

Try—Avoid using *try* as a noun meaning *effort* or *attempt.*

Correct: He made a good *effort* to enlist the support of the chairman.

LIST 3

Business Jargon

Advise—Use *advise* for *to give counsel;* to indicate that information is conveyed use *inform, tell, write,* or some other specific word.

Correct: I have been asked to *inform* you that Mr. Harold Jones will be in Detroit on June sixth.

Asset—Use *asset* for *part of one's property;* to describe *something useful* choose an exact term.

Correct: He considered his bonds his principal *asset.* He will be a good salesman in our department. His friendliness is his most valuable *trait.*

As per—Avoid this phrase.

Correct: I am sending you the information you requested in your letter of June third. (*not* as per your letter of June third)

Balance—Use *balance* for money; for part of a sum or group, use words like *rest* or *remainder.*

Correct: He completed the *rest* of the experiment. He used the chemicals he needed and sent the *remainder* to Laboratory A.

Claim—*Claim* means to *assert ownership of* or *to demand as due. Claim* used for *assert* or *maintain* is colloquial.

Correct: He *claimed* the prize even though his paper had been submitted late. He *maintained* that the equation could be solved.

Contact—Avoid using the verb for *to establish a business or social connection. Prefer meet, interview, speak to, speak with, consult.*

Disinterested, uninterested—*Disinterested* means *impartial; uninterested* means *without interest.*

Correct: The moderator in a labor dispute should be *disinterested.*

Expedite, facilitate—*Expedite* means to *accelerate progress* or *to hasten; facilitate* means *to simplify, to make accomplishment easy.*

Correct: The central communications system *expedites* delivery of office memoranda. Elimination of two printed forms and the second interview *facilitates* hiring.

For free—The use of *for* is unnecessary.

Correct: He received the reprint *free.*

Words like *line, field, factor, proposition* are often used loosely. *Line,* for example, is frequently vague or unnecessary.

Incorrect: He is in the chemical engineering line.

Correct: He is a chemical engineer.

Incorrect: He is in the chemical line.

Correct: He sells (or manufactures) chemicals.

Literature—Avoid using the term for *printed circulars and other advertisements.*

Correct: He printed ten thousand *pamphlets* for the firm. The survey of office *notices* revealed excessive duplication. He preferred French *literature.*

On the order of—Avoid using *on the order of* for *like.*

Correct: He ordered more rings like those we have now.

Per—*Per,* which is correct in Latin phrases like *per annum* and *per capita,* should be avoided with English forms.

Correct: Fifty gallons an hour, ten grams a pound, five hundred dollars a week.

LIST 4

Common Examples of Wordy and Incorrect Diction in Technical Writing

A.c., d.c.—Avoid the expressions *a.c. current* and *d.c. current* because *a.c.* and *d.c.* are abbreviations for *alternating current* and *direct current.*

All of—*Of* is unnecessary.

Weak: The rule applies to all of the data in Table 1.

Improved: all the data.

At above
At around
At below
} *At* is unnecessary.

Incorrect: This loss of oxygen occurs at above 100° F.

Correct: at 100° F. . . . around 100° F. . . . below 100° F.

Cannot help but—The double negation (*not* and *but*) is unnecessary.

Incorrect: The librarian *cannot help but* notice the need for faster distribution of technical articles.

Correct: The librarian *cannot help* noticing the need for faster distribution of technical articles.

Combined together
Continued to remain } Avoid unnecessary and ineffective repetition of ideas in other words. This fault is known as *tautology* or *redundancy*. The following examples are common: *few in number, first initiated into, important essentials, in the same way as described, join together, joint partnership, my autobiography, large in size, throughout the entire*. Prepositions are often used unnecessarily. See *up* and *with*.

Doubt but what—The phrase should be *doubt that*.

Incorrect: The authors *doubt but what* increased heat will change the values in Table 4.

Correct: The authors *doubt that* increased heat will change the values in Table 4.

Down—See *up*.

Equally as good—Avoid using this phrase for *as good as* or *equally good*.

Incorrect: Felt filler is *equally as good as* plastic in this model.

Correct: Felt filler is *as good as* plastic in this model.

Incorrect: Felt filler is *equally as good* in this model.

Correct: Felt filler is *equally good* in this model.

Few in number
First initiated into } See *combined together*.

Has got to—Avoid using this phrase for *must* or *should*.

Incorrect: The water pressure *has got to* be maintained.

Correct: The water pressure *must* be maintained.

Important essentials
In the same way as described
Join together
Joint partnership
My autobiography } See *combined together*.

Of—Avoid using *of* superfluously in such expressions as *feel of, smell of, taste of, inside of, off of, out of,* and *outside of*.

Incorrect: The change will occur *inside of* five minutes.

Correct: *in* five minutes.

Incorrect: The filler should be placed *outside of* the filter.

Correct: *outside* the filter.

Outside of—Avoid using *outside of* for *except* or *besides* in formal writing.

Example: This applies to all minerals *except* (*not outside of*) copper.

Recur again
Regain again
Repeat again } *Again* is unnecessary.

Incorrect: If the dust is not filtered the first time, the procedure should be *repeated again*.

Correct: . . . should be *repeated*.

Refer back
Retreat back } *Back* is unnecessary.

Incorrect: All questions about procedure should be *referred back* to the supervisor.

Correct: . . . *referred* to the supervisor.

Throughout the entire—See *combined together*.

Up—*Up* is unnecessary in such expressions as *climb up, connect up, count up, divide up, end up, link up, pay up, rest up, show up, speed up, write up*. Avoid also unnecessary words in expressions such as *advance forward, check off, connect up with, descend down, enter in, enter into, empty out, pay out*.

Incorrect: Professor Jones will *write up* his speech for the convention booklet.

Correct: Professor Jones will *write* his speech for the convention booklet.

Incorrect: The introduction of larger quantities will *slow up* the first step of the process.

Correct: The introduction of larger quantities will *slow* the first step of the process.

Incorrect: The problem of *emptying out* the tank safely has not been solved.

Correct: The problem of *emptying* the tank . . . .

With—*With* is unnecessary in the expression *over with*.

Incorrect: At this point the most difficult computation is *over with*.

Correct: . . . *is over*. . . . *is completed*. . . . *ends*.

With and *up* are both unnecessary in the expression *meet up with*.

Incorrect: The authors did not *meet up with* this phenomenon often.

Correct: The authors did not *meet* this phenomenon often.

LITERATURE CITED

1. Handbooks of Composition

Hodges, John C., "Harbrace Handbook of English," Harcourt Brace and Company, New York (1952).

This good simple handbook is particularly useful for those whose foundation in grammar is not strong. The explanations are clear and simple. It is a useful desk book.

Jones, Joseph, "The Dryden Handbook of College Composition," Dryden Press, New York (1949).

This book will interest those who want a new approach, for the pages are cut in a Dutch door effect with examples on the upper half of each page and the handbook on the lower half. The material on vocabulary is excellent.

Kierzek, John M., "The Macmillan Handbook of English," Revised edition, Macmillan Company, New York (1947).

This handbook has an excellent review of the principles of grammar and a readable, interesting chapter on the development of the English language. It is recommended to those who have some foundation in grammar.

Leggett, Glenn, C., David Mead, and William Charvat, "Handbook for Writers," Prentice-Hall, Inc., New York (1951).

This handbook is suited to college students. It contains a vocabulary test.

Roberts, Charles W., Jesse W. Harris, and Walter G. Johnson, "A Handbook of English," Oxford University Press, New York (1944).

The explanations are clear and simple, and the book contains many exercises.

"Style Manual," General Publicity Department, Union Carbide and Carbon Corporation, Sixth edition (1954).

Alphabetically arranged, this manual demonstrates how comprehensive and useful a manual prepared by industry can be. Its treatment of technical scientific words is sensible, and its consideration of typical errors is obviously the result of long and varied experience with technical writing. It might serve as a model for any company preparing its own handbook.

Thomas, J. D., "Composition for Technical Students," Charles Scribner's Sons, New York (1949).

This handbook contains many excellent examples from technical writing and has useful glossaries. Supplemented by a handbook with a fuller treatment of diction and sentence structure, it will answer most problems in technical writing.

Ulman, Joseph N., Jr., "Technical Reporting," Henry Holt and Company, New York (1952).

This book gives good advice to technical writers who have a little background in grammar and the principles of writing. It considers in detail visual aids in the technical paper and presents a good selection of sample reports and letters.

Woolley, Edwin C., Franklin W. Scott, and Frederick Bracher, "College Handbook of Composition," Fifth edition, D. C. Heath and Company, Boston (1951).

This handbook, which is easy to understand, has good illustrations of rules. The sections on sentence structure and on the letter are excellent.

2. Guides to Reading

"Good Reading," prepared by the Committee on College Reading, Sponsored by the National Council of Teachers of English, Mentor Book, New American Library, New York (1953), $.35.

"The Wonderful World of Books," edited by Alfred Stefferud, Mentor Book, New American Library, New York (1953), $.35.

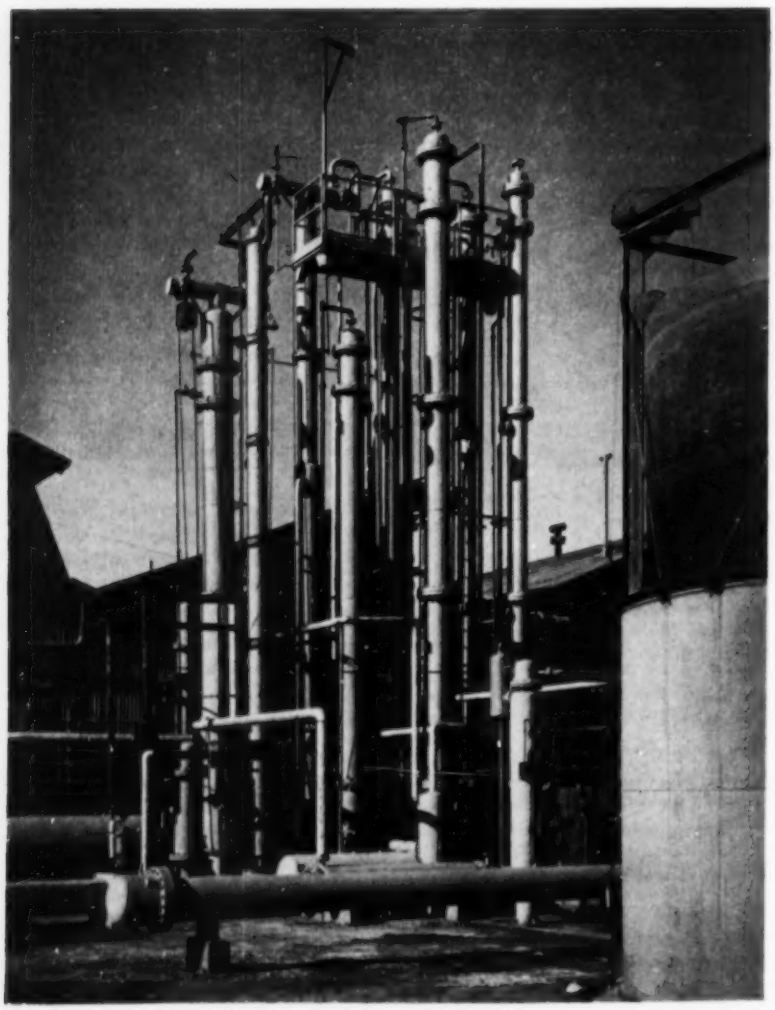
Reprints of this series will be available at 50 cents.

Recent Developments in Wulff Acetylene

Revised calculations show lower costs for acetylene produced by once-through cracking of natural gas.

Marcel J. P. Bogart and Robert H. Dodd

The Lummus Company, New York, New York



Acetylene purification section.

The Various Routes to Making Acetylene

The traditional use of calcium carbide as the source material for acetylene has recently been altered by the commercial production of this important chemical building block from hydrocarbon feed stocks. The abundance of petroleum-derived hydrocarbons and the advent of processes for their transformation to acetylene have successfully challenged the economics of the manufacture of calcium carbide from coal and limestone, which necessitates a large-scale supply or generation of electrical energy.

Conversion of hydrocarbons to acetylene involves satisfying the energy requirements of an endothermic reaction operating at temperatures well above the range normally encountered in petroleum processing. The rigors of conducting a reaction at temperatures as high as 1600° C. (2912° F.) have necessitated the development of special apparatus, processes, and techniques. These developments have reached maturity only within the last decade.

One group of processing routes for the conversion of hydrocarbons to acetylene is characterized by the use of electrical energy, generally in the form of multiple arcs, to satisfy the unusual reaction conditions. These routes accept feed stocks ranging from methane for the Schoch (*9*) and Huls (*4*) processes to heavy distillates as in the Griffin (*5*) and Suits (*11*) processes. At the present state of these processes the energy requirements are of nearly the same order of magnitude as for the calcium carbide route. Arc processes

therefore may not be of interest to the processor who has low-cost hydrocarbon feed stocks at his disposal.

In the second category are those processes wherein the energy requirements are satisfied by the combustion of hydrocarbon-source fuel. An important example of this is the Sachsse, or partial combustion, process (*2, 4, 7, 8*), in which the requisite temperature and energy levels are obtained by the combustion of a portion of the hydrocarbon charge gas with a regulated and limited quantity of oxygen. The resultant gas mixture is thus elevated to cracking temperatures, and the reaction is then suddenly arrested by a water-spray quench to prevent subsequent decomposition of the acetylene so made. This is basically the hydrocarbon processing route employed to date in large-scale plants in the United States.

Elements of the Wulff Process

In the Wulff process (*1, 3, 12*) the energy input is again supplied by combustion, but the fuel is not restricted to the hydrocarbon feed. It utilizes a cyclic regenerative technique of supplying combustion heat to a refractory mass in one step and in a second step releasing the heat so stored for pyrolysis of hydrocarbons to acetylene. Quenching is achieved by transfer of heat from the hot cracked gases to the relatively colder refractory mass downstream of the pyrolysis zone. Although this process has not been employed to date on a large commercial scale a semiworks plant now rated at a production capacity of 1,000,000 cu.ft./month of acetylene has been operated over the past 2 years by the Wulff Process Company in Los Angeles (*3*). This demonstration plant sells bottled acetylene manufactured therein from both propane and natural gas. Experimental operations have also been conducted on ethane and *n*-butane as alternate charging stocks. The demonstration plant has in addition provided experimental data to assist in the proper design and engineering of full commercial-scale Wulff plants.

Figure 1 is a simplified flow diagram depicting the elements of a Wulff process plant. Operation is indicated during that portion of a cycle when Furnace A is being heated and feed stock charged to Furnace B is being cracked. A timer-operated switching system is provided so that after a period of about 1 min. conditions are reversed to crack in Furnace A and reheat Furnace B. The requirement of short residence time for the reaction (as low as 0.03 sec.) is met by operation of the furnaces under vacuum and by use of dilution steam. The combustion and cracked gases are cooled from the normal furnace outlet temperature of about 700° F., quenched and scrubbed, and compressed to atmospheric pressure. The products of combustion are maintained segregated from the acetylene-containing cracked gases and are vented to a stack. The cracked gas flows through a gas holder compressed to 100 to 200 lb./sq.in. gauge, and is sent to a purification unit for concentration of high-purity acetylene. The residual gas from this purification unit supplies the necessary fuel for the cracking step, the remainder being available as fuel for steam generation, gas-engine drives, etc.

The purification unit consists of a train of absorption and stripping columns, wherein the acetylene product is purified by solvent fractionation. The sequence employed begins with a preliminary absorber for the removal of residual moisture, heavy ends, and potentially hazardous higher acetylenes from the cracked gas. This absorbed material is then stripped with a portion of the natural-gas feed stream and returned to the furnaces. The unabsorbed gases from this preliminary absorption step then flow to the main absorber, wherein the acetylene is dissolved out of the cracked gas and leaves the plant residual gas as the overhead stream. The absorber bottoms are sent to a fractionating reboiled absorber, which stabilizes the rich solvent by eliminating contaminants less soluble than the product. The stabilizer off-gas is simply recycled to the inlet to the purification unit. A final purification step separates from acetylene its higher homologs, predominantly methyl acetylene. Rerun facilities are provided to remove water and other impurities from the main solvent circulating stream.

Specific details of the Wulff process, as well as estimates of the manufacturing costs of acetylene produced from natural gas, ethane, and propane have been previously published (*1*). Subsequently significant improvements have been made in this process in an experimental program jointly conducted by the Wulff Process Co. and The Lummus Company. In this period the production capacity was increased fivefold by the addition of two cracking furnaces of twice the throughput capacity of the original experimental furnace. The demonstration plant originally employed as solvents oil for preliminary gas treating, amine for carbon dioxide removal, and acetonyl acetone for final acetylene purification, but it was found that acetonyl acetone could be as effectively used as a single solvent for all three functions. Investigations indicated that a further improvement could be obtained by the use of dimethyl formamide as a single purification solvent. This corresponds to German research (*4*) which reported that butyrolactone and dimethyl formamide had been selected as the two solvents most suitable for a separation of this type. Butyrolactone was favored by the Germans on account of its lower vapor pressure in spite of its lower acetylene solubility and selectivity; however, present performance of the Wulff plant confirmed the superiority of dimethyl formamide over all other solvents tried.

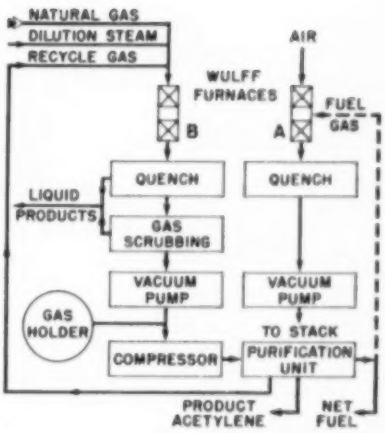


Fig. 1. Wulff process schematic flow diagram.

Further studies have been made to determine the optimum translation of the Wulff process to capacities larger than capacity of the Los Angeles plant. The effect of these factors on the economics of the Wulff process necessitates a revision of the analysis previously presented (*1*).

Figure 1 indicates a recycle gas stream from the purification unit to the inlet of the cracking section. The quantity of recycle depends upon the degree to which any excess residue gas may be used elsewhere. The previous presentation of the Wulff process for natural gas (*1*) was based upon a detailed engineering study of a case wherein the Wulff acetylene plant had no outlet for residue gas over and above that required to satisfy its own energy requirements, including steam generation, compressor drives, etc. This limitation compelled the recycling of a sufficient quantity of this residual gas from the purification unit to obtain near maximum yields. Such an operation, compared with single-pass cracking, is penalized by increased equipment capacity to handle the enlarged gas volumes, as well as lower the acetylene content of the cracked gas due to dilution by hydrogen and other inerts in the recycle gas.

Comparative Economics

As acetylene in large quantities cannot be transported easily over long distances, it is of interest to consider a plant producing acetylene from natural gas as part of an integrated installation including facilities which utilize

Table 1. Material Balance—Wulff Process (a) 50,000,000 lb./yr. Acetylene from Natural Gas

	A. ONCE-THROUGH OPERATION								B. RECYCLE OPERATION							
STREAM	NATURAL GAS FEED		FURNACE EFFLUENT (b)		NET OFF-GAS (c)		PRODUCT ACETYLENE		NATURAL GAS FEED		RECYCLE GAS		FURNACE EFFLUENT		NET OFF-GAS (c)		PRODUCT ACETYLENE	
COMPONENT	M/HR	MOL%	M/HR	MOL%	M/HR	MOL%	M/HR	MOL%	M/HR	MOL%	M/HR	MOL%	M/HR	MOL%	M/HR	MOL%	M/HR	MOL%
Hydrogen	-	-	1,883	59.1	1,696	53.6	-	-	-	-	920	61.2	2,816	58.6	1,371	66.3	-	-
Nitrogen	6	0.3	158	4.1	121	4.5	-	-	5	0.3	81	5.6	241	5.1	119	5.4	-	-
Oxygen	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carbon Monoxide	-	-	305	8.0	224	8.4	-	-	-	-	150	10.3	446	9.4	211	8.9	-	-
Carbon Dioxide	-	-	53	1.4	40	1.5	0.7	0.29	-	-	31	2.0	88	1.8	42	2.0	0.7	0.29
Methane	1,033	93.2	1,070	28.1	828	30.5	-	-	1,018	93.3	288	19.0	803	17.0	376	17.5	-	-
Ethane	92	4.7	2	0.1	2	0.1	-	-	71	4.7	1	0.1	3	0.1	1	0.1	-	-
Ethylene	-	-	37	1.0	28	1.1	-	-	-	-	5	0.3	13	0.3	6	0.2	-	-
Acetylene	-	-	269	7.0	5	0.2	293.0	99.34	-	-	10	0.6	289	5.7	12	0.5	293.0	99.34
Propane	28	1.3	2	0.1	2	0.1	-	-	21	1.3	2	0.1	5	0.1	1	0.1	-	-
Propylene	-	-	2	0.1	1	-	0.2	0.08	-	-	1	-	2	-	-	-	0.2	0.08
Methyl Acetylene	-	-	12	0.3	-	-	0.8	0.35	-	-	4	0.6	17	0.9	-	-	0.8	0.35
Butanes + Higher Acetylenes	5	0.3	15	0.6	-	-	-	-	9	0.3	-	-	7	0.1	-	-	-	-
	-	-	10	0.3	-	-	0.1	0.04	-	-	9	0.3	15	0.3	-	-	0.1	0.04
TOTAL	1,164	100.0	3,825	100.0	2,708	100.0	294.8	100.0	1,517	100.0	1,517	100.0	4,729	100.0	2,132	100.0	294.8	100.00
MSCFD BTU/SCF (GET)	17,868 967		34,705 -		24,770 975		2,325 -		13,800 967		13,800 -		43,006 -		19,393 980		-	

(a) Water-free basis. (b) Includes stripper recycle. (c) Wulff furnace fuel deducted.

it as a raw material. Such consumers provide uses for excess residue gas from the Wulff plant, either as fuel (as in a common boiler house for both the acetylene producer and user) or as hydrogen-bearing feed stock for further synthesis operations. It is then possible to take advantage of the economy of eliminating the recycle stream and operating the pyrolysis section on a once-through basis. The differences in processing requirements between once-through and recycle operations may be noted from the material balances in Table 1. These figures are for the annual production of 50,000,000 lb. of acetylene (as 100% C_2H_2), based on a 90% operating factor. The net off-gas quantity shown in Table 1 is the total plant residual gas minus the quantity of this gas used as fuel in the Wulff furnaces.

Detailed process calculations have been made covering the various sections of such a Wulff plant for both single-pass and recycle cracking operations. The plant materials and utilities requirements for these two cases are summarized in Table 2. The design contemplates the use of high-pressure steam-driven centrifugal vacuum pumps and compressor. The process steam required for furnace-feed dilution and the purification-unit heating is supplied by back-pressure turbines. As the prime-mover steam requirements exceed the total process load, the excess is utilized in condensing turbines.

The economics of once-through and of recycle cracking of natural gas for acetylene manufacture at the rate of 50,000,000 lb./yr. by the Wulff process are compared in Table 3. The capital investments shown for the processing plant include engineering costs and contractor's fee, but not such outside service facilities as steam generation, cooling-water supply, etc., as an allowance has been made for these in the utility rates employed. The investment costs shown are based on materials and labor as of January, 1954. The unit rates employed for depreciation, interest, and utilities and materials costs are noted in Table 3 so that proper adjustment may be made for cases where different figures obtain. It should be noted that maintenance labor and administration costs are included in these figures and are based on the same roster of plant personnel previously detailed (*1*).

Table 2.—Materials and Utilities Requirements of 50,000,000 lb./yr. C_2H_2 from Natural Gas

	Units	Once-through	Recycle
Raw materials and By-products			
Natural gas	M std.cu.ft./day	17,868	13,800
Fuel gas:			
Made	M std.cu.ft./day	32,250	27,253
Consumed	M std.cu.ft./day	7,480	7,860
Net	M std.cu.ft./day	24,770	19,393
	M. B.t.u./hr.	490	323
Oils and tars	lb./day	25,000	27,000
Utilities			
Steam, 600 lb./sq.in. gauge, 750° F. TT	lb./hr.	165,200	178,500
Electricity, including lighting and instruments	kw./hr.	401	367
Cooling water	gal./min.	12,000	12,000
Process water	gal./min.	90	115
Chemicals			
Solvent make-up (estimated)	lb./day	450	500

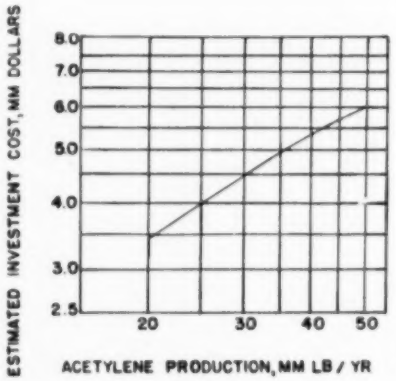


Fig. 2.

The investment cost of the processing unit of a Wulff plant of capacities lower than 50,000,000 lb./yr. is given in Figure 2 for once-through cracking. Figure 3 shows the effect of both production rate and natural-gas value on the manufacturing cost of acetylene, which was determined as detailed in Table 3. The residual-gas credit has been taken at the same price per British thermal unit as the charge stock, although it may be more valuable as a source of hydrogen or synthesis gas. Liquid products and tars have been credited with only fuel value in spite

Table 3.—Estimated Manufacturing Costs for 50,000,000 lb./yr. Acetylene from Natural Gas

Cracking operation	Once-through		Recycle	
Natural-gas price, ¢/MM B.t.u.	15	20	15	20
Capital investment				
Acetylene process plant	$6,057,000	$6,057,000	$6,720,000	$6,720,000
Solvent and product inventory	52,500	52,500	52,500	52,500
Real estate	3,000	3,000	3,000	3,000
Working capital (3 months)	613,600	636,600	659,400	684,800
Total	$6,726,100	$6,749,100	$7,434,900	$7,460,300
Annual capital charges				
Depreciation @ 10%/yr.	$ 605,700	$ 605,700	$ 672,000	$ 672,000
Interest on capital @ 3.5%	235,400	236,200	260,200	261,100
Misc. taxes and insurance @ 2%	121,100	121,100	134,400	134,400
Total	$ 962,200	$ 963,000	$1,066,600	$1,067,500
Annual operating charges				
Cost of natural gas	$ 851,000	$1,135,000	$ 658,000	$ 877,000
Credit for net fuel gas *	610,000	803,000	412,000	530,000
Net raw-material charge	241,000	332,000	246,000	347,000
Steam @ 40¢/M lb.	521,000	521,000	563,000	563,000
Electricity @ 0.62¢/kw.hr.	19,600	19,600	17,900	17,900
Cooling water @ 1.5¢/M gal.	85,000	85,000	85,000	85,000
Process water @ 15¢/M gal.	6,400	6,400	8,200	8,200
Solvent make-up @ 33¢/lb.	49,000	49,000	54,200	54,200
Labor and administration †	225,000	225,000	225,000	225,000
Maintenance supplies @ 4%	242,300	242,300	268,800	268,800
Royalty, etc., @ 1/4¢/lb.	125,000	125,000	125,000	125,000
Total	$1,514,300	$1,605,300	$1,593,100	$1,694,100
Total annual expense	$2,476,500	$2,568,300	$2,659,700	$2,761,600
Manufacturing cost, ¢/lb.	4.95	5.14	5.32	5.52
Return on investment, % ‡	18.2	17.5	15.3	14.5

* At same price per British thermal unit as the natural gas; includes $30,000 credit for oils and tars.
† Includes operating and maintenance labor; see (1).
‡ After income taxes @ 52% of gross profits; based on 10¢/lb. sale price.

of their desirability as a source of aromatics.

Comparison with Alternate Routes

Manufacturing costs for acetylene from hydrocarbons by the various routes have been published by Happel and Marsel (*6*) and Sherwood (*10*), but these costs were not based on so detailed a design as, and are therefore in disagreement with, the results presented herein. Furthermore, they did not include the recent improvements in the Wulff process.

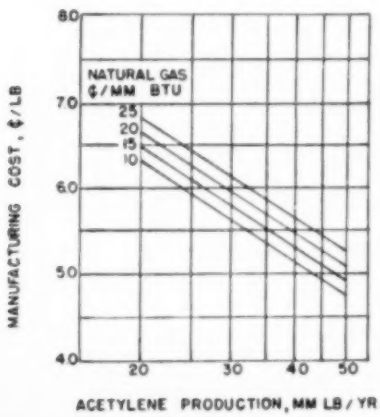


Fig. 3.

The different character of the primary energy input precludes a general comparison between the Wulff process and the arc routes. Also, no specific details of today's version of the partial combustion process having been published it is difficult to compare it accurately with the Wulff process.

The major economic advantages of the Wulff process lie in the absence of a large electrical energy requirement and in the fact that an oxygen plant is neither necessary nor desirable. Of importance to processing is the separate combustion step which prevents dilution of the pyrolysis gas by products of combustion and results in no appreciable production of carbon black as this is deposited on the refractory during cracking and is subsequently burned off.

Matthews (*8*) reports the necessity of removing excessive quantities of contaminants such as hydrogen, olefins, and carbon monoxide from the feed to a partial combustion reactor to prevent troublesome preignition. By contrast, the presence of such contaminants in the feed to the Wulff demonstration plant furnaces when purification-unit residue gas is recycled to the cracking step has not affected operability. It is therefore possible to operate a Wulff plant on mixed charging stocks such as refinery off-gas blends without preliminary feed preparation. Such a plant may also be designed to operate on various alternate feed stocks without seriously affecting the maximum acetylene production capacity. Also acetylene and ethylene may be manufactured simultaneously in varying proportions.

Summary

Economic data on the Wulff process for the manufacture of acetylene by the pyrolysis of natural gas are presented covering the range of production of 20,000,000 to 50,000,000 lb./annum. A comparison is made between single-pass cracking operations yielding residual fuel gas as a by-product, and recycle cracking wherein the ultimate yield is increased to the point of fuel self-sufficiency for the acetylene generating plant alone. An economic optimum is reached when other facilities exist for the utilization of any excess fuel from the single-pass pyrolysis operation.

Literature Cited

1. Bogart, M. J. P., G. R. Schiller, and C. J. Coberly, *Petroleum Processing*, **8**, No. 3, 377 (1953).
2. Carter, A. S., *F.I.A.T. Rev. Ger. Sci., Final Report* 988 (April 11, 1947).
3. Coberly, C. W., and G. H. Bixler, *Ind. Eng. Chem.*, **45**, 2596 (1953).
4. Dennis, N., J. F. Ellis, and A. W. C. Taylor, *B.I.O.S. Final Report* 1048 (April 30, 1947).
5. Von Ediger, W., U. S. Patent 2,632,731 (March 24, 1953).
6. Happel, J., and C. Marsel, *Chem. Ind. Week*, p. 17 (April 28, 1951).
7. Holroyd, R., ed., *C.I.O.S. Report* XXX-103 (Aug. 16, 1945).
8. Matthews, M. A., *B.I.O.S. Final Report* 877 (Sept. 25, 1948).
9. Schoch, E. P., *Univ. Texas Pub. No.* 5011 (June 1, 1950).
10. Sherwood, P. W., *Petroleum Refiner*, **27**, 573 (1948).
11. Suits, C. G., U. S. Patent 2,353,770 (July 18, 1944).
12. Weaver, T., *Chem. Eng. Progr.*, **49**, 35 (1953).

Presented at A.I.Ch.E. San Francisco Meeting.

CAST HEAT ALLOY REFERENCE SHEET

N. S. MOTT, Chief Chemist and Metallurgist

The Cooper Alloy Foundry Co., Hillside, N. J.

Alloy: Heat Resistant 25% Chromium 12% Nickel Alloy.

Designations: A.C.I. HH; A.S.T.M. A297-49T Grade HH; S.A.E. 70309.

Chemical Analysis: C 0.20-0.50%; Cr 24-28%; Ni 11-14%; Si < 2%.

Applications: Used for economical high temperature structural applications. Typical uses are furnace shafts, beams, rails, and rollers; oil tube supports; dampers and valves; kiln ends; burner diffusers.

Machinability: Machines fairly well.

Heat Treatment: Used in "as-cast" condition.

Weldability: May be readily welded using a type 309 welding rod. No heat treatment after welding is necessary.

TYPICAL MECHANICAL AND PHYSICAL PROPERTIES

	Room Temperature:		1400° F.	1600° F.	1800° F.	2000° F.
	As Cast	Aged *				
Tensile Strength, 1000 lb./sq.in.	90.5	95	35	20	11	6
Yield Point, 1000 lb./sq.in.	41	39	18	14	7	
Elongation %	32	21	12	16	30	49
Reduction in area %	33	27				
Brinell Hardness	170	198	96	59	44	

* 24 hr. @ 1400° F. furnace cooled.

Charpy Impact (Std. Keyhole ft.-lbs.)	15			
Mod. of Elasticity (X10⁶ lb./sq.in.)	28			
Density (lb./cu.in.)	0.279			
Melting Point (° F.)	2500			
Specific Heat (B.t.u./(lb.)/(° F.)) @ 70° F.	0.12			
Thermal Expansion (x 10⁶ in. (in.) (° F.)) ° F.	70-1000	9.6		
	70-1500	10.8		
	70-2000	10.8		
Thermal Conductivity (B.t.u./(hr.) (sq.ft.)(° F./ft.)) ° F.	70-212	8.2	70-1500	14.3
	70-1000	10.9	70-2000	16.4
Electrical Resistance (microhms/cu.cm.) @ 32° F.)	85			

HIGH TEMPERATURE STRENGTH: (lb./sq.in.)	1400° F.	1600° F.	1800° F.	2000° F.
Stress Rupture (100 hr.)	13,000	6,500	3,500	1,800
Stress Rupture (1000 hr.)	9,200	4,800	2,500	1,100
Creep (1% 10,000 hr.)	6,000	3,500	2,000	750

MAX. (° F.) TEMPERATURE FOR CORROSION RESISTANCE:

Air Oxidation Resistance	1950
Oxidizing Sulfur Bearing Flue Gas (Low Sulfur)	1950
Oxidizing Sulfur Bearing Flue Gas (High Sulfur)	1850
Reducing Sulfur Bearing Flue Gas (Low Sulfur)	1950
Reducing Sulfur Bearing Flue Gas (High Sulfur)	1800

High Temperature Corrosion Resistance:

Molten Drawing and Tempering Salts ..... Fair
Molten Cyaniding Salts ..... Fair
Molten Neutral Salts ..... Fair
Molten High Speed Salts ..... Fair
Molten Metal Resistance ..... Good resistance to molten lead. Not resistant to molten aluminum or magnesium.

Carburization Resistance:

Pack Carburizing ..... Fair
Gas Carburizing (< 15% CH_4) ..... Excellent
Carburizing in Natural Gas High CH_4) ..... Poor

General High Temperature Characteristics:

This alloy has good high temperature strength and has fairly good ductility and impact resistance. It has fair resistance to thermal fatigue and the effect of cyclic heating. Its hot hardness is fairly high.

No. 35

◀ Maroon Bells.

Colorado River—This here krick's the one that cut the mighty Grand Canyon on its way to the Pacific. You'll find the Boulder Dam, now sometimes called Hoover Dam, downstream 'bout 1,000 miles. ▼

FALL MEETING

Glenwood Springs, Sept. 12-15, 1954

By Ross Tedter U. S. Bureau of Mines, Rifle, Colorado

THE TRAIL LEADS TO COLORADO

HOWDY PARDNER!

This here's a personal invite from th' Rocky Mountain Section to visit th' West in September for the Glenwood Springs National Meeting. Come early and stay late. For your visit we picked out Glenwood Springs cuz it's smack in the middle of Colorado's mountains and lakes and it ain't so high up (5,758 feet) you'll need conditioning. To be real honest—*ethical* you call it—we had a heck of a ruckus before Glenwood was picked cuz there's so many purty spots in these parts t' choose from.

Settled on September for th' meeting cuz we got a lot of aspen trees that change color when the frost hits 'em and they take on every color of the rainbow. Folks 'round here are so proud of these aspen trees that we even named a town after 'em. Fishin' season is still on at that time and you'll get a real bang out of catchin' some mount'n trout.

For them that reads, there'll be a whole passel of technical papers. We got a lot of natural resources out here what are going to be discussed.

Neither Flat Nor Fancy

Now fer the nontechnical side of the meeting. In place of tellin' you right off what we got, we're gonna do it the easy way by tellin' you what we ain't got. We ain't got no great big towns like New York or Chicago, and outside of Denver, none of them skyscraper office buildings. Out here, most of our skyscrapers 're God-made. Mount'n peaks under 14,000 feet ain't been counted yet and are considered low country. Like Gov'nor Dan once told the flatlanders, if all of Colorado was spread out level, it would make the state of Texas look mighty small. He oughta know, too, cuz he rijinally come from Texas.

Somethin' else we ain't got in these parts is fancy ways. We're just plain folks 'round here and mostly we just

wear levis and a checkered shirt. If you've got an outfit like that, bring it along, or if you ain't, we'll round up one for you. Also, we ain't got a formal banquet, but, pardner, did you ever taste a chuckwagon Bar-B-Q?

Pictures Ahead

Tell you what we have in store for you. First off, we better tell you where Glenwood Springs is situated. Glenwood is a little mount'n town located where the Roaring Fork runs into the Colorado River, about 160 road miles west of Denver and 370 miles east of Salt Lake City. We got a real fancy place to bunk you down—Hotel Colorado. This place is real modern with inside plumbin' and that sort of thing. Besides good vittles, the hotel throws in a lot of extras, sech 's swimmin' in the patio pool, mineral baths, golf, midnight snacks, and so on. The golf course ain't nothin' fancy but the view is mighty purty. By the way, the hotel has a saloon too, if you want to wet your whistle on occasion.

If you want a bit of unusual entertainment, there's the Red Mountain ski lift just six blocks from downtown. This is a mile-long chair lift that takes you about 1,600 feet 'bove the town. We're sure sorry we can't offer you any skiing, but it's just too early in the season for that. Anyways, you'll get a lift and see the scen'ry.

If you like to hike, there's a lot of possibilities. There's a trail up Lookout Mount'n that's only two miles from downtown. There's a hike to the Cave of the Clouds at the edge of town, and if you're real serious about your hikin', there's a trip to Hubbard's caves that's eleven miles.

For you would-be cowpunchers ther'll be a before-breakfast ride on a nice gentle cayuse at seven each mornin' of the meetin'. The trip is up Lookout Mount'n. A real wrangler will go 'long with each group.

There'll be square dancin' right after the chuckwagon dinner. Some of the local dance sets will git things t' rollin'.

If you like fishin', and who don't, there's a whole raft of trout streams and lakes in these parts. Just to name a few, there's the Roarin' Fork and Fryin' Pan Rivers and Trappers Lake.

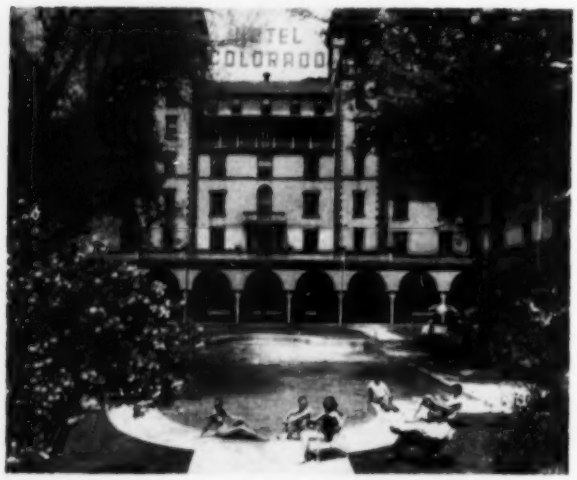
One trip you'll want to take is to Aspen, the old silver minin' town of the past that's gone dude. You'll ride the new-fangled elevated to the top of Ajax Mount'n. Another mighty fine trek is up the Crystal River to Marble. This is a right purty drive to a honest-to-gosh ghost town.

We could go on and on about these purty scenic trips, but 'nstead, we'll ask you to visit the information booth set up in the lobby of the Colorado Hotel throughout the meetin' to help you pick out other trips you want to take.

Nothing to Wear?

Here's some tips about the clothes you'll need. A jacket will feel mighty good over that checkered shirt after dark. Some comfortable shoes (or western boots) that ain't so new you'll mind gettin' 'em scuffed up are practical if you plan on ridin' or hikin' 'round in the hills. The ladies should plan on casual sports dress.

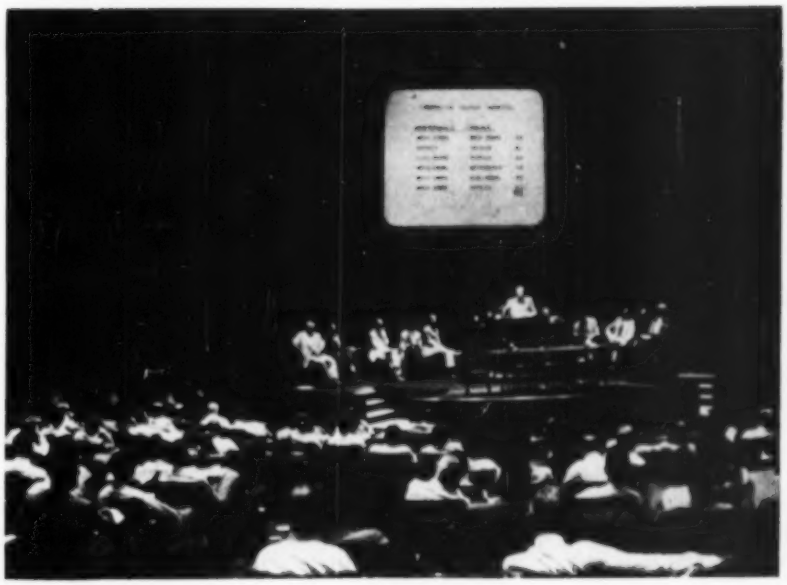
Well, pardner, we're sure lookin' forward to your visit and we'll see you in September.



Some bunkhouse—I'd say.

Mount Sopris is so purdy that most folks takes its picture.

Thar's a pond suspended on the mount'n side that ya might wander up to if ya take a notion—called Hanging Lake.



"Industry returns to the campus" ► might best describe the International Congress on Nuclear Engineering held at the University of Michigan. 84% of registrants were from U. S. industry. In the scene at right the training of nuclear engineers was under discussion.

▲ Exterior view of Rackham Building (in background) where majority of meetings, plus industrial exhibition, were held.

Only woman delegate from abroad—Maria A. Vigon, a nuclear scientist from Spain, tries out a remote manipulator in the industrial exhibit. ▼

National Meeting Report

PART I

By John Mellecker

Ann Arbor, Mich. Late June, 1954: First national meeting for Institute's Nuclear Engineering Division brought out 1,076 with 117 from 20 other lands. Subjects ranged from peaceful nuclear technology to the problems we face in attempting to achieve competitive industrial application under the burden of restricted flow of nonweapons information.

The net result to hundreds of "average" chemical engineers was the catching-up with nuclear developments. For the nuclear experts present, however, theirs was expectedly different. Confided one senior delegate from Europe: "It was a unique opportunity to talk with others from so many different places. Technical papers were good, if they did sometimes end just a little too soon. The most interesting thing was to be able to chat with the industrial people here—they're the ones who'll be tackling the big applications. The fact that firms show enough interest to send all these men, indicates that things are soon going to be happening in the U. S."

Troubled Enthusiasm. There is little doubt about our being at last in high gear. And we are headed up a road leading to nuclear power and other benefits from the atom. It will, however, be a rough road. At this International Congress, opportunity was given to see further up this road than had heretofore been afforded. The sight, although promising, uncovered a major dilemma which has been confronting our nation's leaders and pictured a changed world in which some nations, previously hampered by lack of resources, will be in a different position in the future.

The policy we have followed in re-

The "Atoms for Peace" exhibition ► offered displays by 31 firms, government nuclear establishments and university groups. Shown here is part of one of the industrial exhibitor's booths.

stricting material from general distribution—nuclear information not having any direct bearing on military weapons—was taken to task by a group of speakers. Most vehement, perhaps, was newspaper publisher Paul Block, Jr., who said "the Japanese fishermen know far more about an H-bomb explosion than do I . . . ."

Exit Monopoly. The Atomic Energy Act of 1946, long decried as the chief stifling agent of our traditional Yankee initiative, will be liberalized, according to predictions from most of those present and in a position to know. "It was" reminisced former chairman of the A.E.C. Gordon Dean, "written at a time when we thought we had a monopoly . . . We should have known better; but at least the men who wrote these provisions [having to do with sharing information with our allies] into the law felt that such measures would delay the time when a potential aggressor would get the bomb . . . Perhaps they did albeit it slightly . . ."

Lending his support to Administration efforts to bring about a liberal revision of the Act, Dean called for (1) a continuation of our out-stockpiling Russia, (2) lifting very rapidly the wraps of secrecy from everything in our program in the nonweapons area and, (3) making possible a bold interchange of information and materials pertaining to the peaceful uses of atomic energy.

Enter Dilemma. While Gordon Dean voiced views doubtless shared by many workers in the field of nuclear technology, a sombre note was interjected by a man with a difficult job, Morse Salisbury, director of A.E.C. information services. How does one judge, asked Salisbury, when something is definitely not in the weapons category? In answering this question, he pointed out that if we could only be sure that "there would be no war for 30 years, virtually all secrecy could be abandoned." "If" he continued, "it were to be next year there should be virtually complete secrecy. A clear solution to this dilemma would only be possible if it were known exactly when the U. S. might have to defend itself in another war."

Having no such information, Salisbury and director of classification for the A.E.C. J. G. Beckerley alluded to the steps under study to take us out of our secrecy defense mechanism, which we precipitously entered into upon finding ourselves, at the end of the war, confronted by the Soviet Union as an unfriendly power. In acknowledging the magnitude of the sociological problem, Beckerley ended his remarks, "I recognize that limiting atomic energy to purely weapons information is a matter for future action. There will need to be considerable public discussion and possibly some Congressional action before the Commission could undertake such a program. However, I should like to predict that, just as it is inevitable that competitive nuclear power will be developed, so it is inevitable that peacetime nonweapons technical information will in time be essentially completely unclassified."

"Our dilemma" commented C.E.P. editor-publisher F. J. Van Antwerpen, in his remarks opening the symposium on release of nuclear information to the people, "arises from failure of the political processes . . . not the scientific . . . ."

The burning question about dissemination of information to those of our people who need it is: When, and whether in time?

FIRST NEWS OF NUCLEAR POWER AS A FACTOR IN COLD WAR STRATEGY

Morse Salisbury had finished his luncheon address. Then came an innocent-sounding question from the floor having to do with changes anticipated in the philosophy on publicity about peacetime nuclear-power applications. Salisbury's answer, however, was immediately taken to be a major revelation of attitude on the part of the Eisenhower Administration. Said Salisbury, Reactors for nuclear power are rapidly coming to be regarded as an "element of strategy of the cold war. . . . That is to say, the nation which leads the way into practical demonstrations of nuclear power has gained for itself in the spectrum of world opinion considerable advantage. It enjoys a much more favorable climate of opinion among the nations that are on the teeter tatter than the nations which have fallen behind in the race." Thus an innocent question opened a new phase of our era of dilemma.

Question . . . . . Answer

Communications Comeback

When Michigan professor of journalism Wesley Maurer mailed 1,000 invitations to editorial writers, publishers, columnists, etc., to join in a study of mass communications, he felt sure a major accomplishment was near consummation. When, weeks later, only a few fellow-journalists had indicated willingness to attend his mass communications conference on nuclear energy developments, Wesley felt quite taken aback. But not for long. If journalists couldn't (it turned out there were two conflicting meetings) get around to learning about nuclear things, there was another angle. Maybe nuclear engineers would be interested in boeing-through some of the problems faced by journalists. Undaunted by his first reverse, Maurer reorganized his forces into a briefer program (the Salisbury luncheon and two evening sessions). Result: An outstanding highlight of the entire congress. Scientists' ways of reticence about publicity were decried by Watson Davis (Science Service), Paul Block, Jr. (Ohio & Pennsylvania newspaper publisher) and J. Luntz (McGraw-Hill editor). Defending were Allan Astin (Bureau of Standards), John Grebe (Dow Chemical) and Duane Roller (A.A.A.S. editor). Mixed consensus: Less ivory-towerism, Mr. Scientist, and more care towards accurate reporting, Mr. journalist!

Maurer's other evening session, chairmaned by F. J. Van Antwerpen (editor and publisher of C.E.P.) dealt with release of nuclear information to the public. Blue-ribbon panel included James G. Beckerley (director of classification, A.E.C.), Shelby Thompson (A.E.C.'s chief, public information service), Paul Block, Jr. (newspaper publisher) and Oliver Townsend (Atomic Industrial Forum). Beckerley's remarks have already been referred to. Thompson defended the information-dispensing activities of the A.E.C. and Townsend dealt with the status of other countries (see page 37).

Block Lets Go. The scene was the large amphitheater shown in the picture at the top of page 35. Speaker after speaker had read his statements, interestingly, if somewhat dispassionately. Then it was Paul Block's turn. An educated man of unusual breadth for these times, Block soon held his audience spellbound. Assuming the role of fun-poker and critic of everything hallowed with professional mysticism and ostentatious dignity, Block cut a wide swath. ("A medicine man is a fellow who takes the supernatural and uses it to enhance his income") On the nuclear side, Block sees the trend of judging most discoveries as having military potential, as a mistake that has been made before in history by overmilitary conscious governments. He particularly deplored the Salisbury revelation about nuclear power as an element in the cold war, as certain to impede the very result we need: practical, operating plants.

There was little doubt among the audience that Paul Block, Jr., was opening his heart and mind in a manner of

PEOPLE WHO WILL BE CHANGING THE PATTERN OF THE WORLD'S ENERGY BALANCE

Comments on nations' nuclear activities quoted from Oliver Townsend's paper "Nuclear Energy the World Over."

Top row, l to r: Gunnar Randers, NORWAY ("shares * * * [with the Dutch] a reactor at Oslo . . . Has largest heavy water plant in Western Europe . . . also has uranium in mind as a possible future fuel for her merchant marine".); S. S. Bhatnagar, INDIA (". . . may, in the long range, be one of the leaders in atomic energy development and utilization. Has uranium, beryllium and thorium"); F. E. Prieto, MEXICO ("may have uranium and has announced plans to build a reactor soon"); C. Rennie, GREAT BRITAIN ("has access to uranium . . . plants in which to process it . . . very active program for development of power reactors . . . strong incentive").

2nd row: Thomas Coulter, SOUTH AFRICA (major source of uranium from gold ore tailings—editor); Nils Hidle, NORWAY; Dragoslav Popovic, YUGOSLAVIA (no information); Anker Hansen, DENMARK ("has some of the best nuclear scientists in the world but no uranium").

3rd row: German Mendivelzua, ARGENTINA (no information); Jose M. Otero, SPAIN, ("has some uranium, and Europe's second largest heavy water plant. Has a * * * reactor under design, and hopes ultimately to build an atomic power industry"); Ugo Facchini, Carlo Salvetti and Sergio Gallone, ITALY ("which has plans for a nuclear reactor but has not yet allocated the money").

Bottom row: Maria A. Vigon, SPAIN; Rudolpho Busch, ARGENTINA; J. M. W. Milatz, NETHERLANDS, ("sharing a * * * reactor [with Norway], using uranium purchased from Belgium before the war and * * * hidden from the Germans"), and a couple of unidentified thinkers.

Further information on other countries, next month.

---

rare candidness, to stimulate his fellow citizens, thinking on subjects he sees in ominous historical perspective.

Impact Upon Society

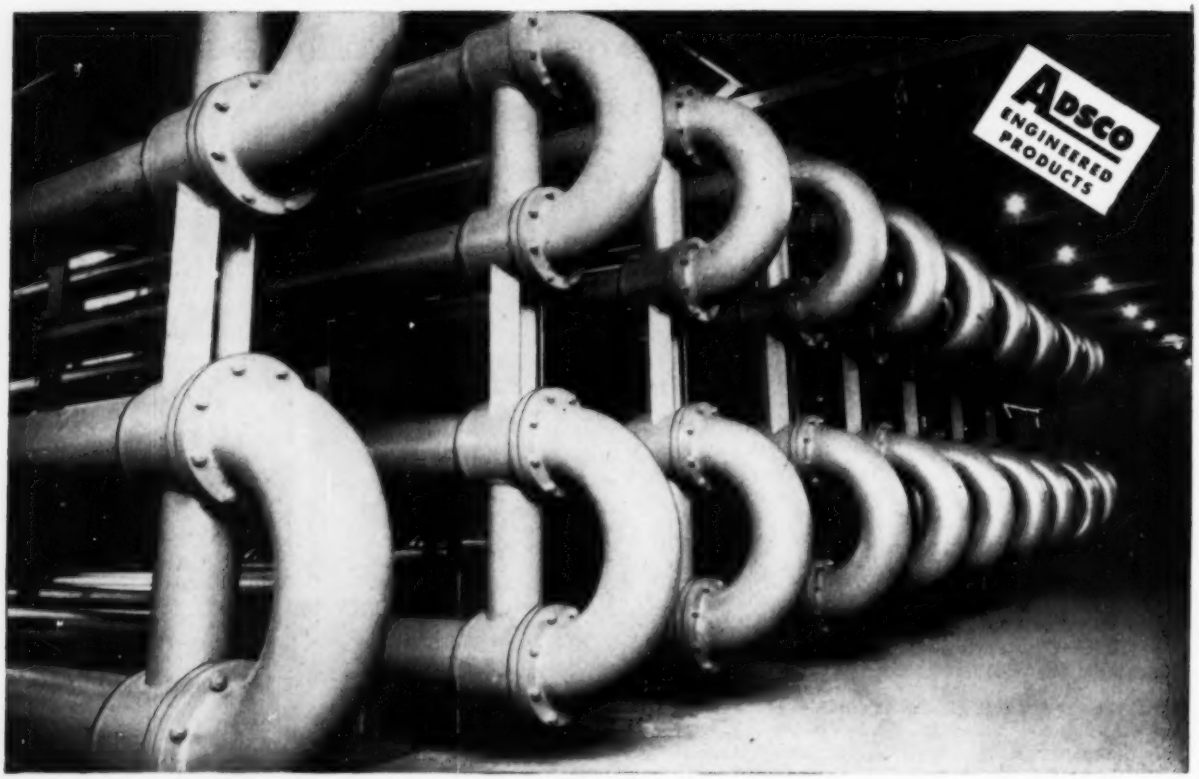
Institute Vice President Dodge called for the technologist to accept responsibility of helping to guide thinking of those who are having to cope with the sociological problems of the nuclear age. In his morning session health, safety, and the reaction of the individual citizen were covered. But the most stirring effect was generated by a religious man, Dr. Elton Trueblood, recently made chief of religious information, U. S. Information Agency.

After the Bomb. One day soon after the first atomic bomb had been successfully detonated Trueblood was summoned to join with several of the scientists who had been involved. Never, said Trueblood, has he been among men who evoked such wonder as to what the world will be like in the future. Four insights needed today are, according to Trueblood: Antidotes to (1) absolute despair, (2) easy optimism, (3) insensitivity to use of nuclear weapons and, (4) recognition that the ultimate solution will be spiritual.

After the Luncheon. Van Antwerpen's continuing session on the sociological problems heard discussion on education, military tactics, scientific research and the law. It will be no easy task, gloomed U. Michigan Prexy Hatcher, "to move with all energy and speed to dissipate the dark clouds of gloom and terror * * * , to train and direct men in the vision and the skill to move its power over into spaceful applications, and to adjust our social and governmental agencies to absorb the new dimensions of life imposed by this new force conjoined with its caravan of aircraft, radar and attendant electronic devices . . .". As to the problem of the educators themselves, "we have had nothing quite like it in urgency or in dimension in our past experiences."

Research Warfare. "The absence of such [scientific weapons—such as radar] is directly attributable," said L. V. Berkner, president, Associated Universities, Inc., "to the technological delays resulting from secrecy. Had airborne radar been developed and advertised openly, the consequent great progress in these developments might have so weakened the German confidence in their submarine supremacy, or in their capabilities for strategic air attack, *that*

(Continued on page 42)



NEW CELLULOSE PLANT SALVAGES MAXIMUM HEAT WITH THESE 40 ADSCO HEAT EXCHANGERS STACKED IN SERIES

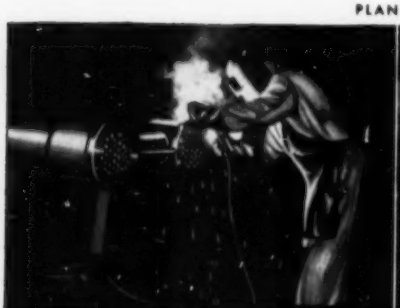
High efficiency in the causticizing department of a new cellulose plant erected by one of the largest concerns in the country is achieved by these ADSCO Heat Exchangers. In the process, one liquid must be cooled, the other heated. The ADSCO exchanger thus accomplishes two jobs in one. To achieve the small terminal temperature differences desired, counterflow design, with the exchangers in series, was necessary. Straight-tube, fixed-tube-sheet construction was selected as the most economical design.

Liquid in the tubes passes from one tube bundle to another through the 180° elbows at the ends; liquid in the shells passes from shell to shell through the short vertical connecting pipes. Hot corrosive liquor holds no terror for these exchangers because tubes and tube sheets are of stainless steel . . . These 40 exchangers are evidence of the contribution which ADSCO can make to the sound engineering required in chemical and petroleum processing plants. . . . Your ADSCO representative invites inquiries.

AMERICAN DISTRICT STEAM COMPANY, INC.

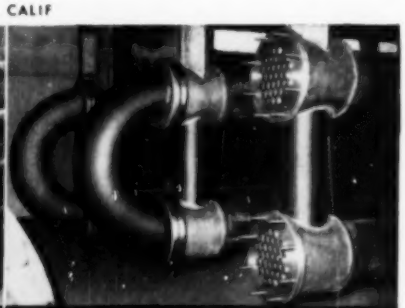
NORTH TONAWANDA, NEW YORK

PLANTS: NORTH TONAWANDA, N. Y. — RICHMOND, CALIF.



ADSCO is widely known for the high quality of its welding. Here, a workman is welding a support to shell of exchanger.

To eliminate stress while heat exchanger is in operation, tubes are roller expanded into tube sheets while unit is steam heated.



ASME construction throughout. Shell design pressure, 200 lbs.; test, 400 lbs. Tube design pressure, 150 lbs.; test, 300 lbs.

Ideal for mildly corrosive service

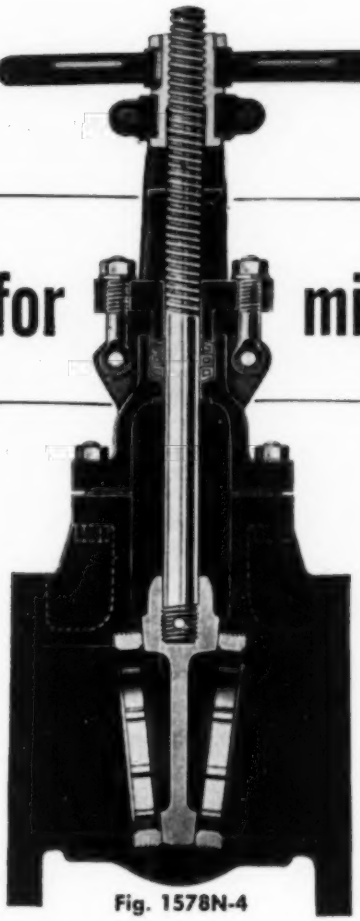


Fig. 1578N-4

3% Nickel Iron Gate Valve, Class 125 lb. . . . for process industries . . . developed and produced by The Lunkenheimer Co., Cincinnati 14, Ohio. Outside screw and yoke, bolted bonnet, flanged . . . face to face dimensions are American Standard for 125 lb. Cast Iron Wedge Gate Valves (ASA B16.10-1939).

LUNKENHEIMER develops new 125 lb. nickel-iron valve for process industries...

Mildly corrosive valve service poses a particularly tough problem in the process industries. To get *maximum* corrosion resistance, you have to pay for more than you need—high-alloy valves are expensive. And yet, ordinary cast iron often won't do the job.

An economical answer to many of these problems has been developed by Lunkenheimer with this new line of Nickel-Iron Gate Valves. Bodies and bonnets are 3% Nickel-Iron, for better corrosion resistance than ordinary cast iron, and trim is offered in choice of 18-8 (Type 316) Stainless Steel or Monel®, for maximum resistance at the point of most severe service. This combination is cutting valve costs in the petroleum field, pulp and paper, wood treating, and scores of other process industries.

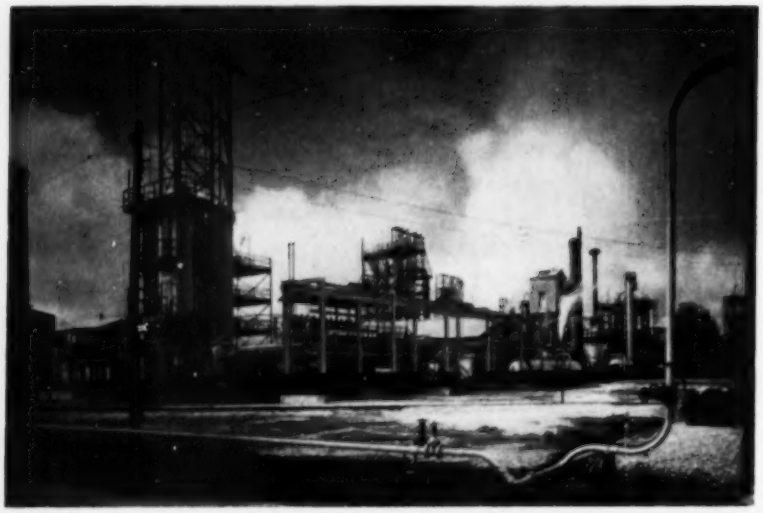
This development is but one more instance that shows how nickel alloys can be used to provide significant advantages, whatever the equipment.

Many standard nickel alloyed compositions are available, making it easy to select one with extra qualities for almost any specific use. Whatever your industry, if you have a metal problem, send us details for our suggestions. Write today.

INCO

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N. Y.

GULF OFFERS ALCOHOL FROM NEW TEXAS PLANT



Gulf Oil Co. has recently opened an iso-octyl alcohol plant at its Port Arthur, Texas, refinery as part of a program to convert its raw materials into chemicals. Iso-octyl is the first high-grade chemical produced by the company for sale on the open market.

Gulf Oil Corp. marks its initial move into the general organic chemical market with the shipment of iso-octyl alcohol from a new plant in Port Arthur, Texas. With a capacity of about 9 million pounds annually, the new plant can be adapted to several other Oxo syntheses and can produce nonyl, decyl, tridecyl, and other higher alcohols.

The process utilizes heat, petroleum hydrocarbons, carbon monoxide, hydrogen, and a metal catalyst in the first stage to produce octyl aldehydes, which are purified in a second stage. In a third step the purified aldehydes are converted to iso-octyl alcohol by use of active catalyst, heat, pressure, and hydrogen. The alcohol is further purified in the final stage by fractionation. This process is a modification of the Oxo process introduced by the Germans during World War II.

GRANTS TO CHEMICAL ENGINEERS IN '54-'55

Graduate and undergraduate programs in chemical engineering are being planned for 1954-55 by leading industrial firms and organizations.

American Cyanamid Co. has established seventeen undergraduate scholarships in chemical engineering and chemistry throughout the country. Students about to enter their junior or senior year will be awarded $600 each for the academic year. In addition, each college will receive $300 for the unrestricted use of the department in question. An existing fellowship program grants $1,500 plus full tuition and laboratory fees to each of fifteen students in their final predoctorate year in chemical engineering or chemistry. The departments in which the students are working also receive $300 each.

Twenty-nine students in the chemical, civil, and mechanical engineering departments at the University of Maine have received $1,200 grants or tuition scholarships from the University of Maine Pulp and Paper Foundation. The students plan to pursue programs in the pulp and paper field.

A fund of $55,000 for fellowships, scholarships, and grants-in-aid to twenty-nine institutions has been established by the American Viscose Corp. for the encouragement of engineering, science, and business administration.

AMMONIA PLANT FOR NORTHWEST

One of the first major chemical and fertilizer plants in the Northwest is being constructed for the Columbia River Chemicals, Inc., at the Atlanta Industrial Site near Walla Walla, Wash., according to a recent announcement by Fluor Corp., which will design and construct the $12,000,000 plant. The urea unit, the announcement adds, will be the first in the West.

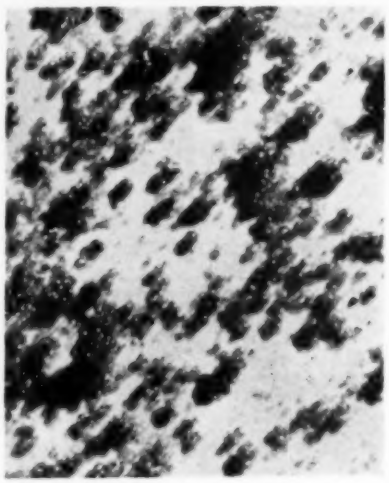
Producing 160 tons of anhydrous ammonia, 110 tons of urea, and 140 tons of ammonium sulfate a day, the plant will be designed to use natural gas as raw material when it is available in the area. Initially the synthetic ammonia plant will generate hydrogen from bunker C fuel oil for combination with nitrogen from the air to produce anhydrous ammonia.

The plant will be located on a 50-acre site under lease from the Walla Walla Port Commission.

INDUSTRIAL SURVEY OF WEST VIRGINIA PLANNED

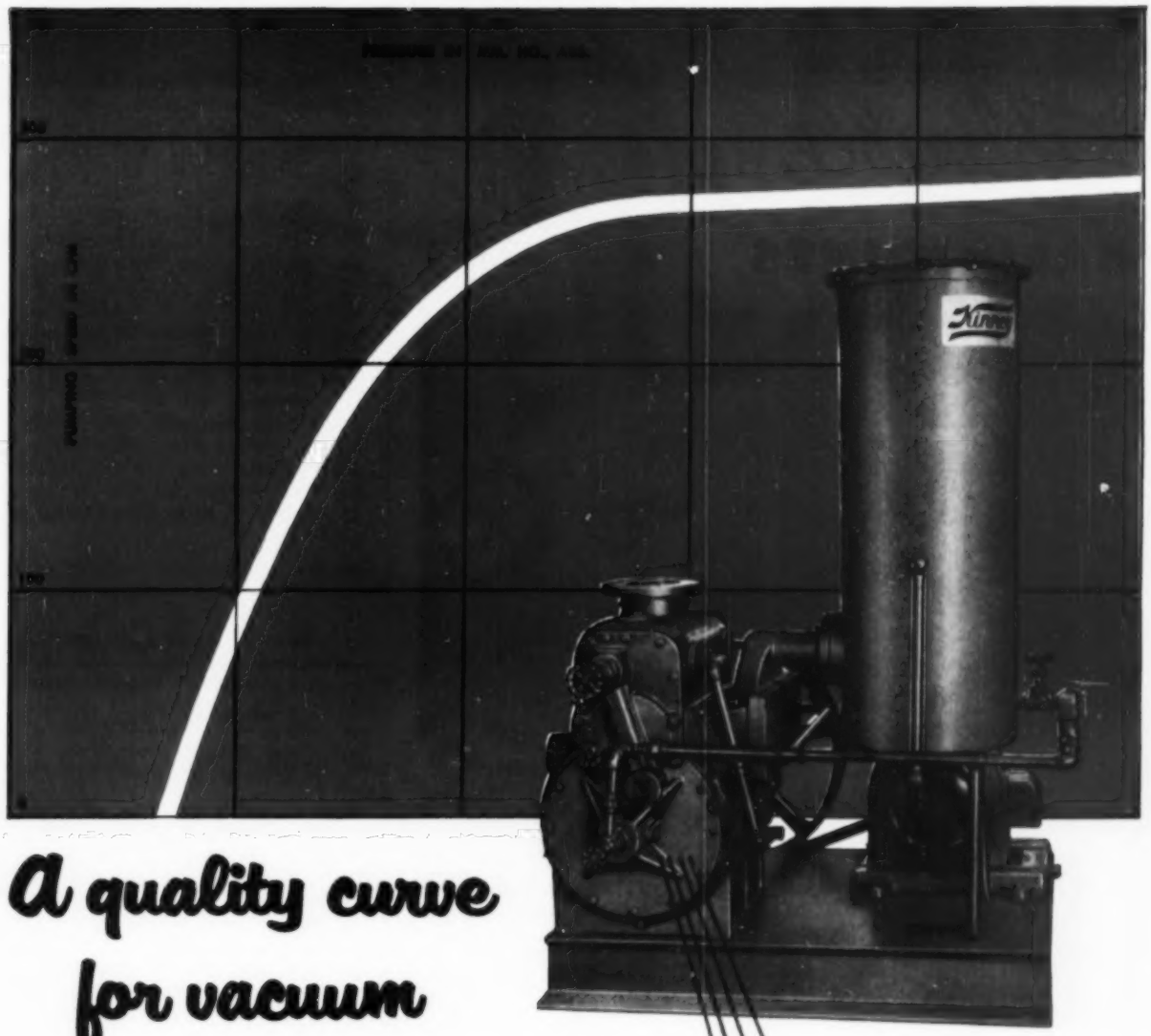
An industrial survey for the government of West Virginia has been announced by Arthur D. Little, Inc., to determine the factors in the state most important to industrial expansion. Included in the review will be mineral and water resources, power and fuel, labor force, available industrial materials, transportation and communication, agricultural raw materials, forest products, industrial sites and plant facilities, availability of finance capital, access to markets, and effects of taxation. The research team will also screen industries to find those of greatest promise and value to the state, as well as investigate specific opportunities within industries already well established in West Virginia. The possibility of expanding industries using wood as a raw material and of establishing small industries in rural localities where labor is available will also be considered.

PLASTIC BALLOONS SAVE OIL



Microballoon spheres of Bakelite phenolic plastic filled with inert nitrogen gas and pumped into a storage tank will reduce evaporation losses of oil by 80 to 90% according to an estimate by Bakelite Co., which markets the spheres developed by Standard Oil Co. of Ohio. Millions of the spheres, which vary from 0.0002 to 0.0036 in. in diam., are pumped into oil storage tanks, where, owing to the wetting action of the oil, they adhere and spread out uniformly on the surface. The layer rises and falls with the level of the oil and prevents the escape of most of the volatile oil fractions normally evaporated. The spheres resist the action of oil and of most corrosive chemicals, such as hydrogen sulfide and salt water. About 60 million dollars worth of oil blown away each year from existing tanks can be saved according to the manufacturer.

(*More News on page* 42)



A quality curve for vacuum

Here's the performance curve for the Kinney 311 cubic foot vacuum pump — *Model DVD 14.9.18.* Where high, fast vacuum is needed . . . in lamp works, power plants, cable impregnating operations, altitude chambers, coaters, and hundreds of other applications . . . this is the pump to pick. Model DVD 14.9.18 maintains high pumping speed in the low absolute pressure ranges . . . the reason why leading process companies depend on this vacuum pump for reliable, efficient operation.

Kinney district offices are staffed with competent vacuum engineers, ready to help you get the right vacuum pump for your needs. Send coupon for complete details.

Free air displacement of 311 CFM at 360 RPM — 15 HP motor.

Designed for easy accessibility of working parts.

Famous Kinney-perfected oil sealed pumping system.

Ask about special design for water-vapor removal.

Kinney

KINNEY MFG. DIVISION
THE NEW YORK AIR BRAKE COMPANY
3548 WASHINGTON STREET • BOSTON 30 • MASS.

☐ Please send Bulletin V51B describing the complete line of Kinney Vacuum Pumps.

☐ Our vacuum problem involves .....

Name .....

Company .....

Address .....

City ..... State .....

BARCO *Flexible* BALL JOINTS

QUICK FACTS

When you need movable joints in piping handling

SULFURIC ACID

THE BARCO BALL JOINT is one of the most useful, most versatile fittings ever developed to provide *flexibility* in piping. The above photograph shows two stainless steel Barco Ball Joints used in making an extension type unloading line for sulfuric acid at a steel mill. This is but one of many installations in industry where Barco joints are used in handling corrosive acids, alkalies, solvents, steam, oil, air, gas, water, and practically all other fluids, *including white fuming nitric acid.*

BARCO BALL JOINTS offer many advantages over ordinary types of joints or flexible connections. When you want to be sure of getting SAFE, long-lasting, trouble-free installations, specify BARCO! Ask our engineers for recommendations. *Worldwide Sales and Service.* BARCO MFG. CO., 560H Hough St., Barrington, Illinois. *In Canada*: The Holden Co., Ltd., Montreal.

1. NO METAL-TO-METAL CONTACT BETWEEN MOVING PARTS. An important Barco advantage where corrosive chemicals are present, either externally or internally.

2. CHEMICALLY INERT GASKETS. Barco offers a choice of seven types of gaskets including No. 11-CT for corrosive service. No lubrication required.

3. STAINLESS STEEL BODIES. Also regularly furnished in Malleable Iron, Steel, Bronze, Aluminum. Other special and alloy joints to order.

4. MAXIMUM FLEXIBILITY. Up to 40° side flexibility with 360° rotating movement.

5. PRESSURE SAFE! FIRE-PROOF! Unequalled for SAFETY where flexible connections are required.

6. MANY STYLES AVAILABLE. Angle or straight; threaded or flanged connections. For pressures to 7,500 psi; temperatures to 1000° F. 15 different sizes. ¼" to 12".

• ASK FOR BULLETIN No. 215

BARCO

THE ONLY TRULY COMPLETE LINE OF FLEXIBLE BALL, SWIVEL, SWING, AND REVOLVING JOINTS

MEET THE

Harding Bliss, professor of chemical engineering at Yale University and fellow of Jonathan Edwards College, will edit the new *A.I.Ch.E. Journal*, to be published for the first time this January.

Professor Bliss, who holds the B.S. degree from the University of Illinois and the Ph.D. from Yale University, was affiliated with the Rohm and Haas Company from 1935-37, served as assistant professor at the University of Pennsylvania from 1937-39, and has been at Yale University from 1939 to the present.

His fields of interest are thermodynamics, reaction kinetics, ion exchange, oxygen manufacture, and distillation of pure water from sea water. During World War II he served as consultant

NATIONAL MEETING report

(*Continued from page 37*)

the war might have been prevented altogether . . . ."

The impact of nuclear energy on scientific research in general, referred to by several speakers, resulted in "the development of large-scale scientific and technological cooperation brought about by the importance and magnitude of the field, by the diverse nature of the problems and applications, and by the size and costliness of many of the necessary technical facilities" according to L. J. Haworth, director, Brookhaven National Laboratory.

New Chain Reaction? "It is to be fervently hoped that this meeting will serve to ignite a chain reaction of cooperation among the scientists of the world and may serve as a rallying point for the extension of his [President Eisenhower's] spirit to other areas of human endeavor which will result in progress toward

Gordon Dean, former chairman, A.E.C., speaking with President C. G. Kirkbride looking on.

NEW EDITOR

to the National Defense Research Committee and to the State Water Commission. He has published papers in technical journals and written sections of Perry's *Chemical Engineers' Handbook* and Tyler's *Chemical Engineering Economics.*

Harding Bliss

It is a pleasure to welcome so distinguished a scholar and so popular a member of the Institute to the editorial ranks and to wish him and the *A.I.Ch.E. Journal* many happy new years.

---

that goal of mutual understanding and cooperation which is the prelude to a peaceful world." These were the words of C. E. Larson, director, Oak Ridge National Laboratory, who credited discoveries in the nonnuclear field as having made the latter successes possible.

Without Scholarly Tradition. That is the status of nuclear energy at present, complained A. M. Weinberg, director of research, Oak Ridge National Laboratory, who defined this phase as being recognized when "scientists in a field are not self-conscious or apologetic about pursuing their careers." Secrecy, he said, is the cause.

Send in a Division. As long as two years ago, members of the A.I.Ch.E. were pondering over the need for a cohesive force to unite and provide a meeting ground for workers in nuclear energy as developments approached the large-scale industrial utilization stage

(*Continued on page* 46)

Left: C. E. Larson, director of Oak Ridge National Laboratory. *Right:* J. G. Beckerley, director of classification, A.E.C.

HAMER *Visible Shut-off*
LINE BLIND VALVES

HAMER PLUG VALVES

Will not stick or freeze. Perfect for hard-to-hold fluids. Simple plug adjustment nut eliminates sticking

Hamer Line Blinds are unsurpassed for positive action, easy operation, long-life service and lasting safety. One man can open or blind a line in less than one minute, and there is nothing like a solid plate for a **permanent leakproof shut-off.** Bar or handwheel operation eliminates wedges, hammers, wrenches needed for spreading conventional flanges. Removes fire hazard of sparking and stops damage to equipment.

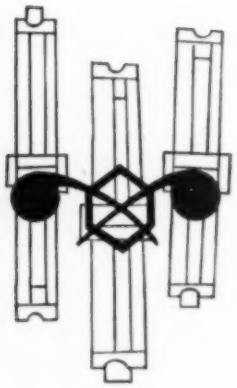
Write for FREE catalog

HAMER VALVES, INC.
2919 Gardenia Avenue
Long Beach 6, California
Representatives throughout to United States

Operation S.P.P.

Irving Leibson and Anthony George Cacoso

U. S. Army Chemical Corps Biological Laboratories, Camp Detrick, Frederick, Maryland



From two chemical engineers currently assigned to research and development work in the Chemical Corps, comes this brief outline of the Army program for utilizing professionally trained inductees. The authors are engaged in chemical engineering process design and development in connection with the biological research program of the Department of the Army, an assignment which is an extension of their civilian professional background and experience. Pfc. Irving Leibson has a Ph.D. degree from Carnegie Institute of Technology and was formerly a chemical engineer with Humble Oil and Refining Company. Anthony Cacoso, also a Pfc., U. S. Army Chemical Corps, has a B.S.Ch.E. from the University of Pennsylvania.

Operation S.P.P. is the Army Scientific and Professional Personnel Program. The identification, classification, assignment, and utilization of technically trained personnel in the S.P.P. program are outlined in Special Regulations No. 615-25-11 of the Department of the Army. The eligibility qualifications for the program vary according to the technical field concerned. For chemical engineers the minimum requirements includes a B.S. degree and 1 year of research experience (or an M.S. degree); for chemists, a B.S. degree and 2 years of research experience (or an M.S. degree). These criteria are based on current Army requirements for technical personnel and are revised from time to time.

How the S.P.P. Program Works

As the first step toward placement in the S.P.P. program, the specific potential capabilities of each inductee are determined by a series of ten aptitude tests. In addition to the education and experience requirements, a score of 120 or higher must be attained by the potential S.P.P. on the section of the aptitude tests characteristic of his field of specialization. Following these tests all inductees are interviewed for classification and identification. Interviewers are continually alert to ensure the proper identification of any individual whose background indicates that he might be eligible for the S.P.P. program. An identification record is completed for each potential S.P.P., a copy of which is sent from the training installation to the Adjutant General. Educational transcripts, letters, and other supporting documents from civilian educational institutions and governmental and industrial organizations, presented by the inductee at the interview, aid in the processing. At the completion of processing at the reception center, the potential S.P.P. is transferred to an appropriate training division for 8 weeks of basic infantry training.

During basic training the S.P.P. identification forms completed at the reception center are reviewed by the Adjutant General, Department of the Army, and matched against approved requisitions for qualified personnel for the technical services, which include the Chemical Ordnance, Quartermaster, Engineer, Signal, Transportation, and Medical Corps. Individuals appropriately assigned to one of these services and performing technical work in their professional field are known as Type A scientific and professional personnel. The Department of the Army keeps a record of all enlisted men so assigned and is informed of every subsequent reassignment or transfer. The S.P.P. initially assigned to a position considered appropriate for a scientific and professional classification remains a part of a special manpower pool, so that the needs of high-priority projects may be closely coordinated with the specific qualifications of any S.P.P. in the overall program. Assignment as Type A personnel depends entirely on the availability of suitable vacancies in the technical services.

Those individuals not selected for a Type A assignment upon the completion of 8 weeks of basic training are known as Type B S.P.P.'s. At the present time approximately 40% of the personnel in the S.P.P. program are in this category. These S.P.P.'s are assigned to a military job or army training school which draws on some significant portion of their civilian training or experience; for example, an astronomer or astrophysicist might be utilized in computing firing data in connection with guided-missiles research. Qualified Type B S.P.P.'s are considered for selection along with other individuals with similar qualifications if and when appropriate Type A assignments become available. In the past year everyone who could qualify for the S.P.P. program has been placed in either the Type A or Type B category.

How the Program Benefits the Individual

There is a definite frame of mind or mental attitude which is requisite for success in this program. The individual S.P.P. must recognize the fact that during his 2 years of military service he is not only given the privilege of continuing his technical career and afforded an opportunity of gaining important professional experience, but also is expected to perform additional duties appropriate to his grade (the "details" normally required from all enlisted men). One might consider the S.P.P. program as a type of graduate training taken without the usual forms of academic guidance. Success in this type of graduate training requires a greater than normal degree of self-discipline, which together with the self-discipline required by Army training helps to mold character and aids in the development of those personal qualities essential for success in later life.

Many of the technical projects in the program of the Department of the Army are of extreme urgency and high priority. In many cases the level of responsibility exercised by the individual S.P.P. working in these projects is higher than that of a similarly trained man in industry. This type of responsibility greatly broadens the mental scope of the young S.P.P. and equips him with the insight and ability necessary for making important decisions

(*Continued on page* 50)

DECREASES MIXING TIME FROM DAYS TO HOURS

Struthers Wells

RUBBER CEMENT MIXER

Struthers Wells Rubber Cement Mixers combine high velocity and streamlined flow with the cutting action of high speed propellers to obtain unprecedented mixing speed with ease of cleaning. Available in capacities from 5 to 500 gallons, jacketed or plain, of any weldable metal. These mixers save time, labor, power and solvent. Vapor-tight "Swift Working" doors and explosion-proof motors minimize fire hazards.

Write for Bulletin 58-W

Struthers Wells

STRUTHERS WELLS CORPORATION

WARREN, PA.

Plants at Warren, Pa. and Titusville, Pa. • OFFICES IN PRINCIPAL CITIES

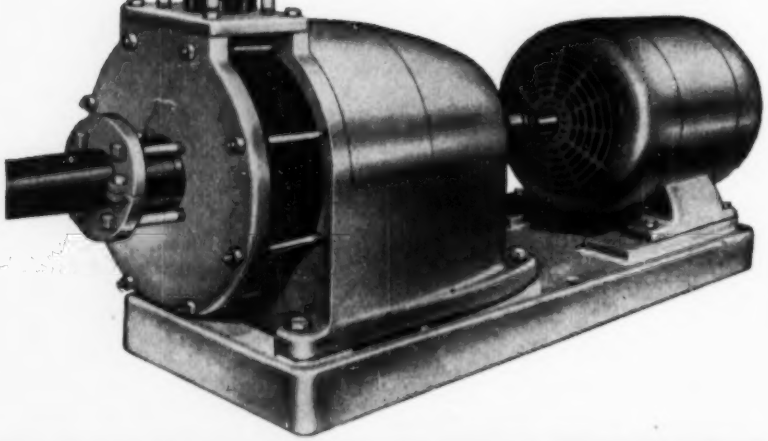
Impervite
IMPERVIOUS GRAPHITE
CENTRIFUGAL PUMPS

gives outstanding service in actual use with 75°C. chlorinated organic acid...

The Department Supervisor of one of the largest chemical companies in the country says, "Your pump is giving us the best service we have ever been able to get for this extremely difficult application. The pump is subjected to round-the-clock service to carry chlorinated organic acid at 75°C. In addition, this IMPERVITE pump has required no maintenance in over five months of continuous operation. I consider this an exceptionally outstanding record."

Featuring simplicity of design, IMPERVITE pumps can be dis-assembled in the field without disconnecting processing lines. All surfaces contacting the corrosive are fabricated from solid IMPERVITE, chemically impervious graphite. Laboratory-accurate machining and precise balance of all rotating parts assures the longest possible leak-proof, maintenance-free service life. IMPERVITE pumps are furnished in a wide range of capacities from 25 to 250 gpm.

Start getting better pumping service immediately in your own process work. Wire, call or write today for complete information on IMPERVITE chemically impervious, maintenance-free pumps.



Falls Industries Inc.

Cleveland's newest industrial suburb

31911 AURORA ROAD • Phone: CHurchill 8-5357 • SOLON, OHIO

(*Continued from page 43*)

and last December a Nuclear Engineering Division of the Institute was formed.

Pediatrical Pains. Like a lustily, squalling infant, the Nuclear Engineering Division underwent a most hectic first week of its official convention life. Already having a membership of 775, of which 60% are nonmembers of A.I.Ch.E., the two business meetings heard proposals for "perfecting" the

D. L. Katz, chairman, Nuclear Engineering Div., A.I.Ch.E., conducting business meeting.

Division that ranged from complete secession, to having the next major meeting overseas (on expense accounts, no doubt). The skill of Chairman Don Katz prevailed upon all to be heard and then to be satisfied with a continuation of the present basis of organization until all concerned can better see what will be happening to nuclear engineering in general, as well as to the Division itself.

Technical Résumé

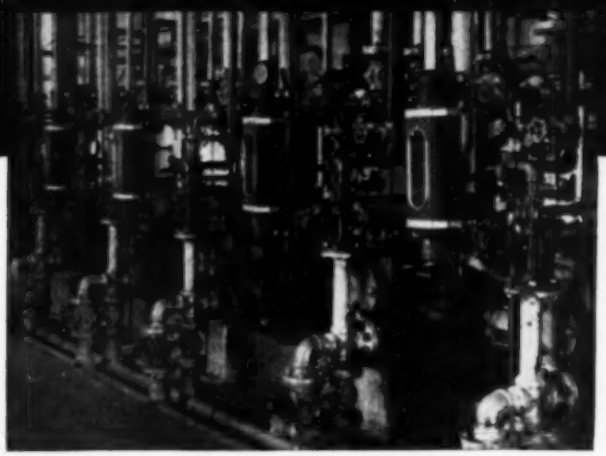
Because of the voluminuous coverage of technical papers at the Ann Arbor meeting, no effort will be made to review them in C.E.P. All papers are available, however, through the May special issue, plus the three Symposium Series volumes on Nuclear Engineering, Vol. 1, now ready. Order all three now: $3.25 each to members, $4.25 to others.

Continued Next Month

Many more pictures of persons and feature events plus reports on the host of interesting sessions that took place during the five and one-half days of the Congress will be published in the August issue.

NO GUMMING! NO CLOGGING! NO LEAKING! NO CORRODING!

WHEN YOU INSTALL DeZURIK PLUG VALVES



In critical valve locations . . . on air, liquid or dry lines . . . where gumming, clogging, corroding or leaking have caused costly shut-downs, why not install a DeZURIK EASY-OPERATING PLUG VALVE on a trial basis?

Time after time, after DeZurik Valves were tested on specific chemical applications, their installation has been standardized on those services. DeZurik Valves won't clog or gum-up . . . they open wide or close tight was an e-a-s-y quarter-turn . . . and there is no danger of contaminating the flow because DeZurik Valves require no lubrication!

For highly corrosive lines, DeZurik Valves can be supplied with Teflon*-faced plugs. (All smaller valves are fitted with Teflon stem seals.) DeZurik Valves are manufactured in a full range of metals offering an almost unlimited choice in the material best suited to the service. In addition, two rubber-lined models are provided: one model with all surfaces exposed to the flow completely lined with corrosion-resistant hard rubber; the other model with soft rubber lining for use on abrasive surfaces.

TYPICAL LINES SERVICED by DeZURIK VALVES

Caustic services
Sulphuric Acid
Chlorine
Resin and Glue
Liquid Latex
Pharmaceuticals
Oxygen
Nitrogen compounds
Compressed air
Petroleum products

DeZurik Valve Features

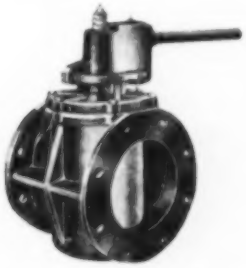
- ✓ ECCENTRIC ACTION
- ✓ ONE-QUARTER TURN to open or close
- ✓ NON-LUBRICATED PLUG
- ✓ RUBBER-FACED PLUG
- ✓ E-A-S-Y OPERATION
- ✓ LEAK-TIGHT CLOSURE

Write for details and recommendations.

* T. M. DuPont

IN ALL SIZES

DeZurik Valves are manufactured in sizes ½" through 20". They can be furnished with threaded, flanged or victaulic ends.



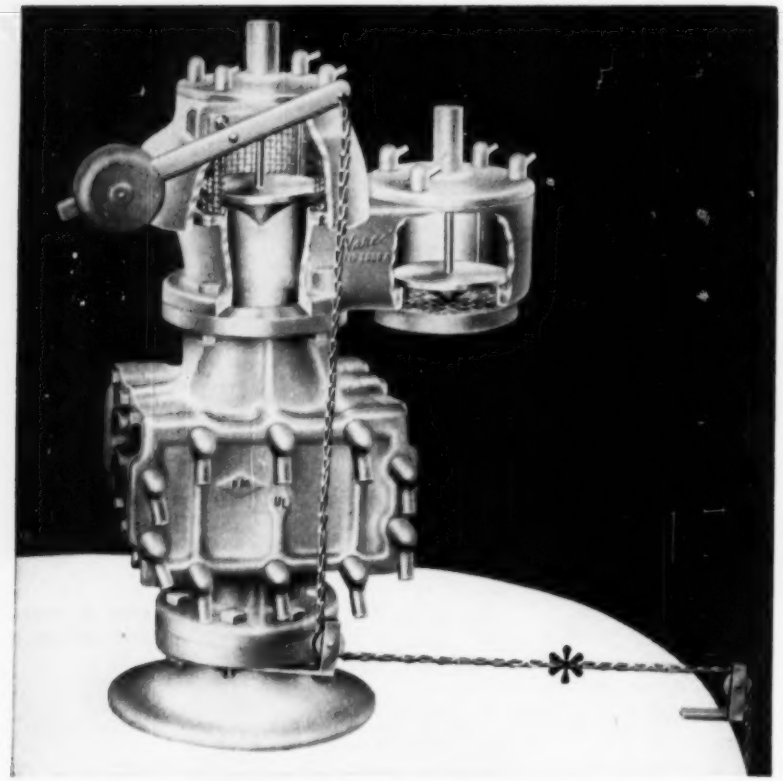
IN ALL METALS

Iron, Steel, Bronze, Acid Resisting Bronze, Ni Resist Metal, Stainless Steel, Monel, Hastelloy, Nickel, Aluminum, Durco Alloys.

IN ALL MODELS

DeZurik Valves are available in lever, gear, hydraulic, air or electric operated models, and with positioning type air and hydraulic operators.

DeZURIK SHOWER COMPANY
SARTELL, MINNESOTA



EFFICIENT VENTING CUTS VAPOR LOSS

Considerable profits are dissipated to the atmosphere when vent pallets warp, stick open or prevent excessive "blowdown." "VAREC" Fig. No. 5800 Conservation Vent Units are ideal equipment for venting volatile or inflammable liquid storage. They protect against dangerous over and under pressures and accidental ignition. Streamlined passages insure maximum flow. Regrindable and renewable metal pallet seats provide extra long life. Drip rings eliminate condensate collection, reducing possibility of freezing. Hyperbolic pallets, loosely guided, prevent sticking and minimize flutter. Flame Arrester unit listed by Underwriters' Laboratories and approved by Factory Mutual Laboratories. Send for free Bulletin CP-2001.

* *Remote Control Flame Snuffer Sheave Brackets, Fig. 130 are optional at extra cost. This assembly is preferable where vent unit is set back from edge of tank.*

"Varec"

THE VAPOR RECOVERY SYSTEMS COMPANY

COMPTON, CALIFORNIA

Cable Address: VAREC COMPTON CALIF. (U. S. A.) All Codes

SALES OFFICE AT:

Boston 11, Mass. — Houston, Texas — San Francisco, Calif.
Chicago 6, Ill. — Minneapolis, Minn. — St. Louis 20, Mo.
Detroit 26, Mich. — New York 7, N. Y. — Seattle, Wash.
Honolulu, Hawaii — Pittsburgh 19, Pa. — Tulsa 9, Okla.

FOREIGN SALES AGENCIES AT:

ARGENTINA, Buenos Aires	H. Hennequin & Cia. Av. Belgrano 881
BELGIUM, Brussels	Etab. Emeric Kroch, 75 Blvd. Clovis
BRAZIL, Rio de Janeiro	Sociedad Importadora de Equip., Av. Calogeras No. 13-7 S/708
CANADA, Montreal	Peacock Bros. Ltd. Town of La Salle
CANADA, Toronto	J. F. Comer Co., 508 Federal Bldg., 85 Richmond St. West
HOLLAND, Amsterdam	Comprimo N. V. Amstel 21C
JAPAN, Tokyo	American Japan Trading Co., 213 Chrom Ginza Chuo-Ku
MEXICO, Mexico City 4, D.F.	Schultz y Cia., S.A., Col. San Rafael, Sullivan 119
SWEDEN, Stockholm	Kemi-Intressen, P.O. Box 16363
SWITZERLAND, Zurich	Uranio-Acessories, Newmuhlequai 24
VENEZUELA, Barcelona	Waldrip-Campbell, Apartado 30
VENEZUELA, Maracaibo	Waldrip-Campbell, Apartado de Correo 594

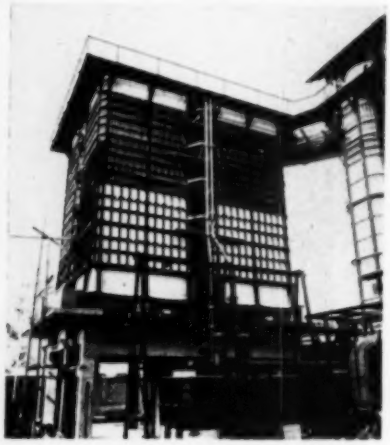
FOREIGN MANUFACTURING LICENSEES:

ENGLAND, London	Wm. Neil & Son, Ltd., 38 Victoria St. S.W.1.
FRANCE, Paris	Compagnie Tech. des Petroles, 134 Blvd. Haussman

58-1

(*Continued from page 46*)

ITALIAN SULFURIC-ACID PLANT



View of plant in Italy producing 120 tons/day of sulfuric acid by the Kacharoff-Guareschi process, described in the August, 1953, C.E.P. Residences are situated as close to the plant as 200 ft. Unplasticized polyvinyl chloride sheets used throughout are shown here. Two smaller plants are being erected in England.

Patented in May, 1954, as U. S. Patent 2,678,872, the process is licensed through International Processes, Inc., Chicago.

ENGINEERS TO MEET IN BRAZIL IN AUGUST

Three international engineering meetings are scheduled for Brazil between July 25 and Aug. 12, 1954. The World Power Conference will meet in Rio de Janeiro from July 25 to Aug. 10; the Third Convention of U.P.A.D.I., the Pan American Federation of Engineering Societies, will be held in Sao Paulo from Aug. 2 to 12; and the Fourth Convention of the Inter-American Association of Sanitary Engineering will be at Sao Paulo from July 25 to 31. Further details of the first two meetings were given in the Jan. and Feb. issues of C.E.P., pages 34A and 40A.

Delegates of the Engineers Joint Council to the Brazil meetings include, from A.I.Ch.E., George Lof and Ralph Morgen. Walter Whitman will also attend.

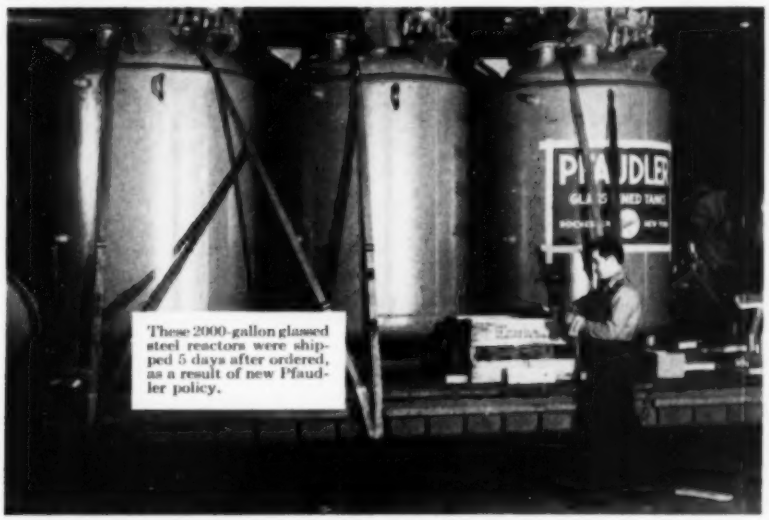
MISSOURI TO GET AMMONIA PLANT

A new $15,000,000 ammonia plant will be erected near Crystal City, Mo., by Mississippi River Fuel Corp., according to an announcement last month. Anhydrous ammonia, ammonium nitrate, and ammonium solutions will be the basic products, which will be produced at an initial rate of about 140,000 tons annually early in 1956.

Corrosioneering News

Quick facts about the services and equipment Pfaudler offers to help you reduce corrosion and processing cost.

Published by The Pfaudler Co., Rochester 3, N. Y.



These 2000-gallon glassed steel reactors were shipped 5 days after ordered, as a result of new Pfaudler policy.

You get a blotter . . . we'll get a packing case

New Fabrication Policy Speeds Equipment

Almost before the ink dries on their purchase order, many chemical processors have been surprised recently to learn that their new Pfaudler equipment would be delivered in a few days.

A new policy of manufacture, emphasizing standard design, makes this possible. This policy is revolutionary in the process equipment industry, and results from Pfaudler's 70 years' experience in supplying glassed steel and alloy equipment to processors. By carefully noting which features are most often required, they have incorporated many "custom" features in standard designs, thus providing maximum flexibility of equipment, with faster delivery.

You can take advantage of off-the-shelf deliveries of glassed steel or alloy reactors, columns, heat exchangers and other equipment by discussing your problem with the Pfaudler representative. Let him recommend, where possible, the *standard* Pfaudler units that incorporate the features you need.

Many of these units are in stock now, waiting to be shipped to you. Call in your Pfaudler sales engineer today and let him help you save time and money.

The Bonnet that Heads Off Corrosion!

Corrosion-proof Hastelloy and glassed steel join forces to resist severe acid attack

Handling pure monochloro acetic acid free of low-boiling acid chlorides requires a heat exchanger that shrugs off relentless corrosive action. To meet this need, New York-Ohio Chemical Co., a subsidiary of Stauffer Chemical Co., turned to Pfaudler corrosioneering.

The answer: Hastelloy "C" for the tubes, and glassed steel for the bonnets, or headers. This combination cuts down on expense as well as corrosion. By using costly Hastelloy only where absolutely necessary, and taking advantage of the less expensive corrosion resistance of glass plus the working strength of steel, substantial savings were made.

To solve problems such as this, Pfaudler corrosioneers enjoy complete freedom in selecting materials. With *every* type of alloy, from stainless steel to titanium, at their disposal they can give you exactly what your process requires. And, when practical, they can also call upon famous Pfaudler high-acid resisting glassed steel.

For an unbiased recommendation on your corrosion equipment problem, talk it over with your Pfaudler representative. Or check the corner card for further information.

How Lederle Keeps Pharmaceuticals Pure

When you've got to cram highly concentrated vitamins or drugs into a tiny pill no larger than your shirt button, you just don't have room for product contamination.

Lederle Laboratories Division of American Cyanamid puts the hex on contamination, at its Pearl River, N. Y. research and manufacturing center, with the two-fisted corrosion resistance of glass combined with the structural strength of steel.

In Pfaudler glassed steel, they found the perfect pilot plant equipment for scale-up from laboratory apparatus. Using 10 Pfaudler glassed steel reactors of various sizes, they have an economical chemical plant that licks corrosion before it starts. Product purity is safeguarded from start to finish of each process.

From pilot plant to full-scale operation, glassed steel reactors provide the corrosion resistance that assures product purity at Lederle's Pearl River plant.

If you have a problem of product contamination, you may get an easy answer by checking the corner card below and mailing it to Pfaudler.

THE PFAUDLER CO., Rochester 3, N. Y.

Please send more information on:

- ☐ Immediate delivery of glassed steel equipment
- ☐ Corrosion materials for_____ process
- ☐ Glassed steel for processing_____

NAME_____

COMPANY_____

ADDRESS_____

CITY_____ ZONE___ STATE____

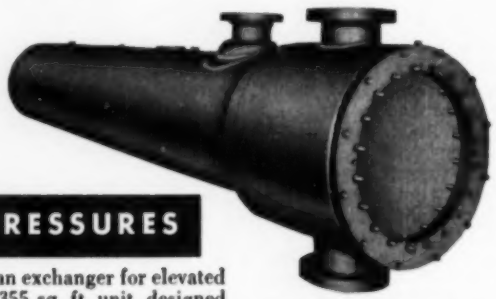
THE ANSWER TO YOUR EXCHANGER PROBLEMS MAY BE HERE

SPECIAL MATERIALS

Perhaps you require special materials of construction, as in the case of this straight tube — fixed tube sheet condenser with compensating shell expansion member. All materials of construction are aluminum except for the steel channels and the backing flanges. All aluminum welds were effected by inert gas shielded arc process . . . or, should you require stainless steel, copper, nickel or Hastelloy construction, our experience assures satisfactory construction.

SPECIAL DESIGNS

Perhaps you require special design techniques as in the case of this double tube sheet exchanger which employs independent tube sheets for each circuit, thereby preventing even a remote possibility of inter-leakage between shell and tube circuit fluids. Our engineering organization is thoroughly experienced in designing exchangers for difficult operating conditions.



ELEVATED PRESSURES

Perhaps you require an exchanger for elevated pressures like this 3,355 sq. ft. unit, designed for a tube side pressure of 900 p.s.i.g. We are regularly manufacturing shell and tube units for pressures up to 3,000 p.s.i.g. and shell and coil units for pressures in excess of 5,000 p.s.i.g.

Whitlock

For recommendations write The Whitlock Manufacturing Company, 97 South Street, Hartford 10, Conn.

Designers and builders of bends, coils, condensers, coolers, heat exchangers, heaters, piping, pressure vessels, receivers, reboilers.

OPERATION S.P.P.

(*Continued from page 44*)

and the stamina necessary for seeing them through.

The professional experience gained by the individual S.P.P. during his period of active military duty should be of great value in his future professional career. Experience gained in the S.P.P. program is at least equivalent to a corresponding period of industrial experience. Each S.P.P. leaving the service receives a statement outlining in some detail (insofar as security permits) the nature and extent of his technical duties. Professional supervisors are always pleased to furnish to industrial personnel men letters of reference concerning individual S.P.P.'s.

Other professional opportunities are provided in that advanced theoretical training for credit is available at most Army installations by contract with accredited educational institutions.

How the Program Benefits Industry

After the completion of 2 years of active military duty, the S.P.P. is separated from the Army and returned to civilian life. The S.P.P. program assures industry a steady stream of experienced, trained scientists and engineers with moral fortitude and a mature professional outlook. Many of the S.P.P.'s returning to industry have gained professional experience not only in research and development work, but also in the various phases of production, including management as well as technical service and quality control.

Conclusion

Since December, 1948, approximately 13,500 men have participated in the S.P.P. program. These men represent 0.6% of the total number of Army inductions and enlistments during this period. The effective utilization of S.P.P.'s during the current continuing shortage of technically trained manpower has contributed materially in executing the mission of the Department of the Army's technical program.

Acknowledgment

The authors acknowledge the suggestions and advice of Lt. Col. John G. Hoffman, Jr., of the U. S. Army Chemical Corps. The statistical data were furnished by Col. F. B. Gregory, G-1, Department of the Army. The authors are grateful for the criticisms and suggestions received from Messrs. C. E. Cottrell, G. B. Achorn, and E. E. Champlin, as well as others. The help of Capt. Joseph Schwimer in the clearance processing is appreciated.

Presented at A.I.Ch.E. Washington, D. C., meeting.

Caustic Soda

for the Soap Industry

Caustic soda is one of the basic chemicals required for the manufacture of modern soaps.

Uniformly high quality GLC GRAPHITE ANODES are basic too—in helping the electrolytic industry meet the growing civilian and defense needs for chlorine and caustic soda.

ELECTRODE DIVISION

Great Lakes Carbon Corporation

Niagara Falls, N.Y. GLC Morganton, N. C.

Graphite Anodes, Electrodes, Molds and Specialties

Sales office: Niagara Falls, N.Y. **Other offices:** New York, N.Y., Oak Park, Ill., Pittsburgh, Pa.

Sales Agents: J. B. Hayes, Birmingham, Ala.; George O'Hara, Long Beach, Cal.; Great Northern Carbon & Chemical Co., Ltd., Montreal, Canada

Overseas Carbon & Coke Company, Inc., Geneva, Switzerland; Great Eastern Carbon & Chemical Co., Inc., Chiyoda-Ku, Tokyo

SPRAYING SYSTEMS CO.

SPRAY NOZZLES

exact performance for every need

Choice of thousands of standard spray nozzles gives you exact spray pattern, capacity, impact and atomization. PROMPT . . . often immediate delivery from stock.

BE SURE TO WRITE FOR . . . .

the most complete spray nozzle catalog ever printed . . . forty-eight pages of detailed information. Write for your free copy of Catalog No. 24.

SPRAYING SYSTEMS CO.

3284 Randolph Street • Bellwood, Illinois

CANDIDATES FOR MEMBERSHIP IN A. I. Ch. E.

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions.

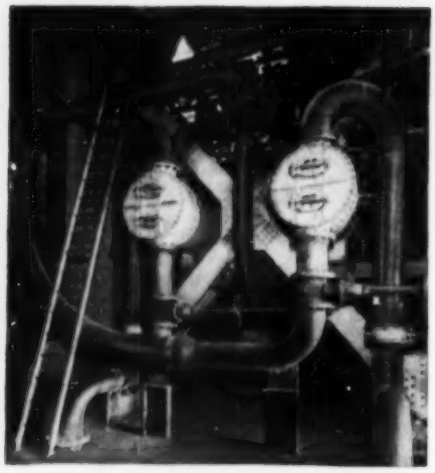
These names are listed in accordance with Article III, Section 7, of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Active members will receive careful consideration if received before August 15, 1954, at the Office of the Secretary, A.I.Ch.E., 120 East 41st Street, New York 17, N. Y.

Applicants for Active Membership

Assman, Frederick F., *Trenton, N. J.*
Bahn, Gilbert S., *Van Nuys, Calif.*
Beatty, K. O., Jr., *Raleigh, N. C.*
Chapin, Jack F., *Reading, Pa.*
Christian, Gene A., *Wilmington, Del.*
Corcoran, Frank L., *Reading, Mass.*
Detlefsen, John D., *Waynesboro, Va.*
Dillon, Robert, *LaMarque, Tex.*
Duffin, John H., *Columbus, Ohio*
Elliott, F. W., *Library, Pa.*
Eustis, Peter, *Portsmouth, Va.*
Frazier, A. W., *E. Alton, Ill.*
Furber, Harold F., Jr., *Wilmington, Del.*
Gates, W. C., *Flossmoor, Ill.*
Goodson, James B., Jr., *Baltimore, Md.*
Green, James A., *Library, Pa.*
Guelzow, Richard W. E., *Monroe, La.*
Hartig, R. George, *Chicago, Ill.*
Helm, Chas. D., *Severa Park, Md.*
Hengstebeck, R. J., *Whiting, Ind.*
Herget, Walter T., *LaMarque, Tex.*
Hesler, Warren E., *New York, N. Y.*
Hiester, Nevin K., *Menlo Park, Calif.*
Holt, Arne B., *Port Washington, L. I.*
Huffman, Robert L., *Wilmington, Del.*
Hughes, Henry E., *West Covina, Calif.*
Hutzler, Leroy, III, *Rome, Ga.*

(Continued on page 68)



HEAT EXCHANGERS
FOR EVERY INDUSTRIAL APPLICATION

"Conseco" designs, builds and installs Heat Exchangers for all process refinery and power plant application; any pressure and temperature; any material; from 1 sq. ft. to 45,000 sq. ft. of heat transfer surface.

Designs include Fixed Head, Packed Head, External Packed Head (in 3 types), Full Floating Head, Internal Floating Head, and Integral Tube Sheet.

We repair, rebuild, retube all types of heat exchanger equipment, regardless of manufacture.

For assured satisfaction—call "Conseco."

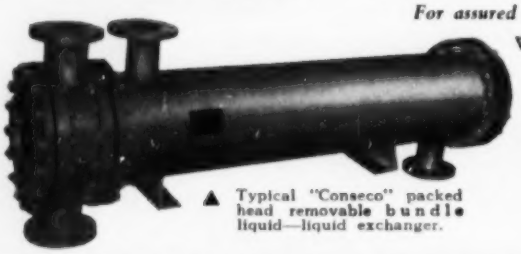
Write for Catalogue.

"CONSECO" PRODUCTS

Retubing
Condensers
Evaporators
Heat Exchangers
Air Ejectors
Flowrites
Tube Plugs
Conco Plugs and Guns
Bevel Gears
Instrument Repair Service
Blackburn-Smith Filters and Grease Extractors
Metal Spray

Bulletins Available for Above Items

▲ Fixed tube sheet, quick opening door, twin "Conseco" coolers for hydrogen cooling installation in large eastern central station power plant.

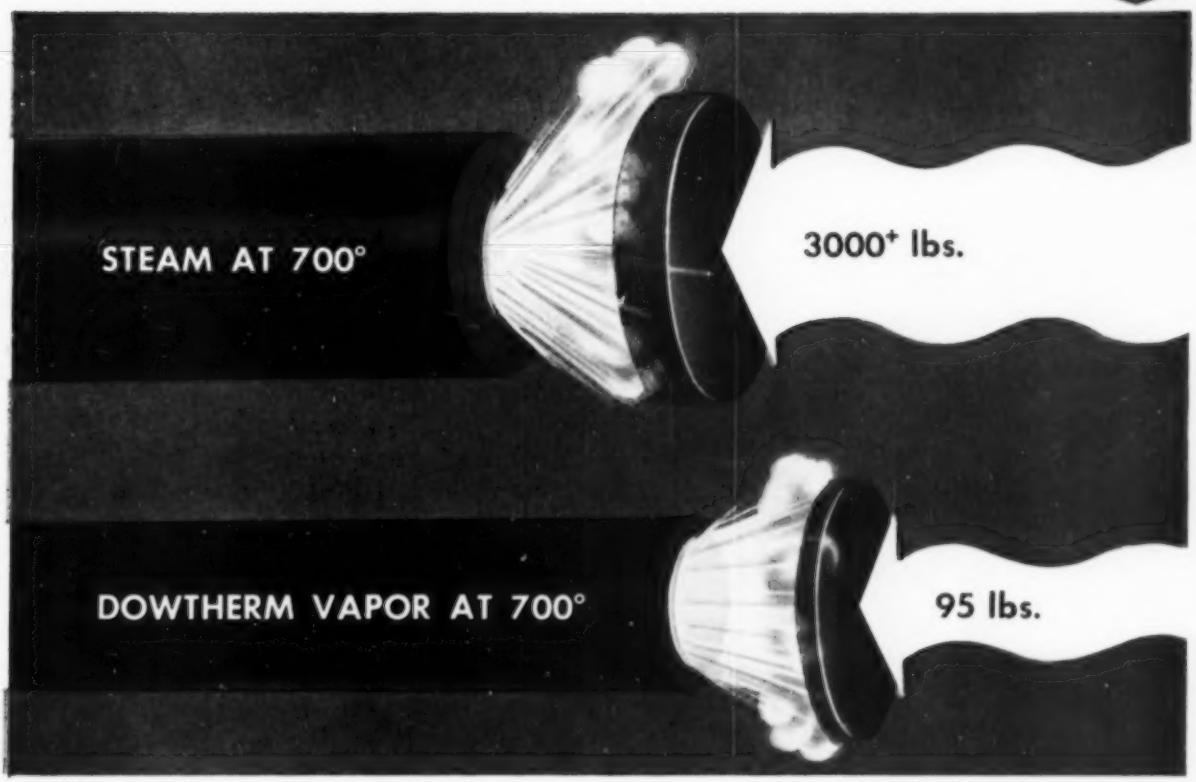


▲ Typical "Conseco" packed head removable bundle liquid—liquid exchanger.

▲ "Conseco" intermediate pressure vapor condenser with U-bend bundle for non-fouling liquid on tube side.

CONSECO Condenser Service & Engineering Co., Inc.

64 BLOOMFIELD STREET, HOBOKEN, N. J. • Hoboken 3-4425 • N. Y. Tel.: BArclay 7-0600



HIGH TEMPERATURES WITH LOW PRESSURES

. . . made possible by the modern heat transfer medium

DOWTHERM

In Plant A, steam at 700°F. exerts a pressure of 3,000 pounds per square inch, while Plant B, using Dowtherm® vapor, obtains the same temperature with a pressure of only 95 pounds per square inch! Translating these facts into your operating temperatures points up one of Dowtherm's big advantages for you.

This lower pressure obviously calls for less expensive, thinner walled equipment, occupying less space. The hazards of high pressure equipment are also avoided and many designs that would be impractical with steam pressure are now made usable with Dowtherm.

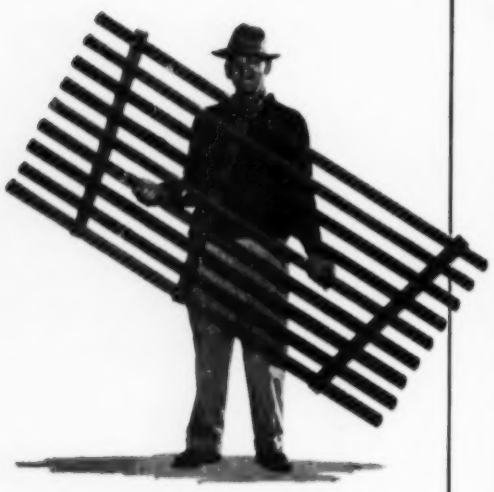
When temperatures get out of control, batches or runs are ruined, shutdowns and equipment replacements are frequent—these are direct causes of reduced efficiency and profits over the years, as you well know. When you install a Dowtherm system in your process, temperature control becomes accurate to a fraction of a degree, forced shutdowns are eliminated and operating costs may be reduced as much as 50%!

Get the facts on Dowtherm now, including details on Dow's unique Analytical and Purification Services. Write to THE DOW CHEMICAL COMPANY, Midland, Michigan, Dept. DO 875A.

you can depend on DOW CHEMICALS

DOW

Examine the filling of a
FLUOR COOLING TOWER
and get the whole story



Fluor uses only 100% clear all heart redwood for filling

Fluor grid decks are not only sturdily built but are made from the highest grade redwood lumber—100% clear all heart redwood—the finest cut of the log. Clear all heart redwood is free from defects and sapwood and under normal controlled water conditions will give many many years of trouble-free service. We invite you to investigate our filling before making your selection of a cooling tower.

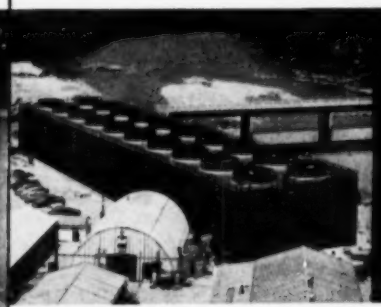
On an average, the price of a cooling tower is based 30% on the mechanical equipment and about 70% for lumber and fabrication. For example, in a Cooling Tower costing $200,000, the mechanical equipment will amount to approximately $60,000 and the tower structure about $140,000. Of this $140,000 about 30% (or $42,000) consists of the filling (grid decks) inside the tower which breaks up the water for greater exposure to air.

The filling is in reality the heart of the tower and its design and construction is of utmost importance. All Fluor Tower filling is mill cut and assembled into grid panels, 2 ft. 10" wide x 5 ft. 11½" long. Nine bars are nailed (with 6 penny copper nails) to three 1x2 cross cleats. The bars are cut on a 25% bevel from 1 x 3 boards; each bar averages 1" x 1½". Grid panels are strong enough to support three 200 lb. men and are actually used as scaffolding during tower erection and inspection. You get more years from a tower with this kind of filling.

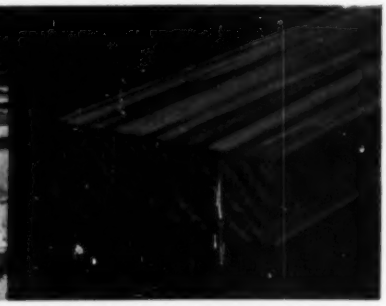
Write for illustrated bulletin "Cooling Water for Industry."

FOUNDER MEMBER CTI COOLING TOWER INSTITUTE

Grid decks easily support three 200 lb. men



A 20-cell Fluor induced-draft cooling tower



A 1x3 makes two bars for Fluor grid decks

BE SURE WITH

FLUOR

THE FLUOR CORPORATION, LTD
LOS ANGELES 22, CALIFORNIA
FLUOR OF CANADA, TORONTO
FLUOR PERUANA, S.A., LIMA
HEAD WRIGHTSON, LONDON

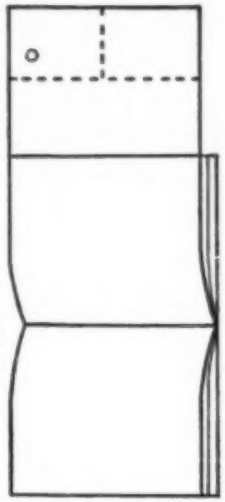
ENGINEERS
CONSTRUCTORS
MANUFACTURERS

NEW YORK
CHICAGO
PHILADELPHIA
BOSTON
PITTSBURGH
SAN FRANCISCO
HOUSTON
BIRMINGHAM
TULSA

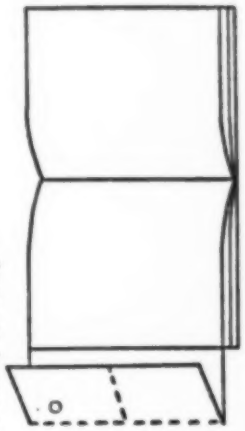
for your information

This C.E.P. information service is a convenient way to get the chemical engineering information you need on the new equipment, on advertised products, on the newly announced developments reported on these pags. A one post card inquiry designed to bring data quickly and easily. Circle the items of interest, sign your name, position, address, etc., and drop in the mail.

Just a moment is needed to learn how to use this insert. When looking through the front part of the magazine pull the folded portion of the insert out to the right, and the numbers on the post card are convenient for marking. THEN . . . .



as you pass the pull-out page, and it is on the left, fold the post card back along the vertical scoring, and once again the numbers are handy for circling.



Postage Will Be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD

First Class Permit No. 48890, Sec. 34.9, P. L. & R., New York, N. Y.

CHEMICAL ENGINEERING PROGRESS
120 East 41st Street
New York 17,
New York

1R 3R 4A 6L 7A 8A 10L 11A

Postage Will Be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD

First Class Permit No. 48890, Sec. 34.9, P. L. & R., New York, N. Y.

CHEMICAL ENGINEERING PROGRESS
120 East 41st Street
New York 17,
New York

12A 13A 14L 15A 16A 17A

PRODUCTS

IFC **Columbia Activated Carbon**
Carbide-designed solvent recovery system.
Carbide and Carbon Chemicals Co.

3R **All-Metal Rotary Sifter**
Motor-driven unit for making particle-size separations on most all dry, powdered, granular, flaked or crystalline materials.
B. F. Gump Co.

4A **Valves**
Pressurized lubricant valves in sizes through 30 in.
Rockwell Mfg. Co.

6L **Ace Condensers**
Complete range of condenser types and sizes.
Ace Glass, Inc.

7A **Solid Porcelain Valves**
Y-valves, angle valves, flush valves, safety valves, and plug cocks.
Lapp Insulator Co., Inc.

8A **Ratio Controller**
Regulates critical gas mixtures in carbon black production.
Minneapolis-Honeywell Regulator Co.

10L **United States Gasket Products**
Features three new catalogs; gaskets and accessories, valve and pump packings, and expansion joints and flexible couplings.
United States Gasket Co.

11A **Vacuum Filters**
Features high submergence (55%) stainless steel drum type filter equipped with compression rolls, string discharge and wash headers.
The Eimco Corp.

12A **Diaphragm Valves**
Working pressures up to 150 pounds, water, air, oil, or gas, 250° F. maximum temperature, depending on valve size.
Crane Co.

13A **Filters**
Rates up to 45,000 gal./hr. Will analyze filtration problems.
Niagara Filters Div., American Machine and Metals, Inc.

14L **Corrosion Resistant Coating**
Applied over any flooring—concrete, asphalt, brick and wood.
Carboline Co.

15A **Induced Draft Cooling Tower**
Winds of 10 to 15 miles/hr. will operate a high Single-Flow at near half design load with fans off, and near design load with fans at half speed.
The Marley Co.

16A **Pumps**
Made to pump highly abrasive slurry. Features solid porcelain plungers.
The Aldrich Pump Co.

17A **Processing Kettles**
Feature double motion agitators equipped with swing-type scrapers which insure positive scraping of the heating or cooling surface.
Buflovak Equipment Div., Blaw-Knox Co.

18A **Centralized Instrumentation**
Complete process instrumentation. Data reduction and automation systems.
Fischer & Porter Co.

19A **Autoclaves**
Equipment for processes requiring pressures from 0 to 100,000 lb./sq.in.
Autoclave Engineers, Inc.

20A **Celite Filtration**
A clarification method which can remove even the finest suspended solids.
Johns-Manville

21A **Twin Dryers**
Two self contained duplicate systems can be operated either singly—or together. Also coolers, calciners and kilns.
The C. O. Bartlett & Snow Co.

22A **Conkey Equipment**
Filters, evaporators and crystallizers now fabricated in CB&I's plants.
Chicago Bridge & Iron Co.

23A **Refrigerating Unit**
Jet water vapor refrigerating units, and pumps.
Ingersoll-Rand

24L **Oil Reclaimer**
Equipment for reclaiming, filtering, purifying and re-refining oil.
The Hilliard Corp.

24R **Mist Eliminator**
Liquid carry-over controlled by separators made of knitted wire mesh.
Metal Textile Corp.

25A **Hydrogen Plants**
Plant produces a continuous supply of hydrogen of a purity exceeding 99.8%. Complete process plants.
The Girdler Co.

26A **Ion Exchange Resins**
Resins remove ash from cane sirup solutions. Also for purification of gelatin, amino acids, fruit drinks, etc.
Rohm & Haas Co.

27R **Safety Heads**
"Circuit-breakers" for pressured systems.
Black, Sivalls & Bryson, Inc.

28A **Dryers**
Truck dryers, large multiple-unit tunnel dryers, single-apron conveyor dryers, and tunnel conveyor dryers.
The National Drying Machinery Co.

29R **Flowmeters**
316 stainless steel bellows. Corrosion resistance and rupture-proof features. Literature.
Barton Instrument Corp.

30A **Steel-Belt Cooler**
Continuous-cooling or conveying hot material processing.
Sandvik Steel Belt Conveyors, Division of Sandvik Steel, Inc.

31A **Nitric Acid Plants**
Designed, engineered and erected.
The Chemical & Industrial Corp.

32A **Pressure Vessels**
Large and small vessels for liquids or gas. Also tanks and stacks.
Posey Iron Works, Inc.

Chemical Engineering Progress

Please do not use this card after October, 1954

1	2	3	4	5	6	7	8	9	10	11	12	14	15
16	17	18	19	20	21	22	23	24	25	26	27	28	29
30	31	32	33	34	35	36	37	38	39	40	41	42	43
44	45	46	47	48	49	50	51	52	53	54	55	56	57
58	59	60	61	62	63	64	65	66	67	68	69	70	71
72	73	74	75	76	77	78	79	80	81	82	83	84	85
86	87	88	89	90	91	92	93	94	95	96	97	98	99
100	101	102	103	104	105	106	107	108	109	110	111	112	114
115	116	117	118	119	120	121	122	123	124	125	126	127	128

Numbers followed by letters indicate advertisements, the number corresponding to the page carrying the ad. This is for ease in making an inquiry as you read the advertisements. Letters indicate position—L, left; R, right; T, top; B, bottom; A indicates a full page; IFC, IBC, and OBC are cover advertisements.

Advertisers' Products

IFC	3R	4A	6L	7A	8A	10L	11A	12A
13A	14L	15A	16A	17A	18A	19A	20A	21A
22A	23A	24L	24R	25A	26A	27R	28A	29R
30A	31A	32A	326A	38A	39A	41A	42L	43R
45A	46L	47A	48L	49A	50L	51A	52T	52B
53A	54A	59A	63A	65A	67A	68L	69R	71R
73R	74T	74B	75R	76T	76BL	76BR	77R	78T
78B	79R	80L	80TR	80BR	81T	81B	83R	84T
84B	85B	IBC	OBC					

Chemical Engineering Progress Data Service

Name .....

Position .....

Company .....

Address .....

City .....Zone .....State .....

☐ I want a subscription. Bill me $6.00 for a year.

July, 1954

Be sure to give name, address, position, etc.

Remember, the numbers on the upper portion of the card bring you data on only the bulletins, equipment, services, and chemicals reported in these information insert pages. The lower portion of the card is for the advertised products, and is keyed not only to advertising pages, but also to the memory-tickling list under the heading Products.

326A **Louisville Dryer**
Rotary coolers and rotary steam-tube dryers.
Louisville Drying Machinery Unit, General American Transportation Corp.

38A **Heat Exchangers**
New cellulose plant salvages maximum heat with 40 Adsco heat exchangers stacked in series.
American District Steam Co., Inc.

39A **Mildly Corrosive Valve Service**
3% nickel-iron, for better corrosion resistance than ordinary cast iron. Many nickel alloyed compositions are available.
The International Nickel Co., Inc.

41A **Vacuum Pumps**
Free air displacement of 311 cu.ft./min. at 360 rev./min. —15 hp. motor. Oil sealed system.
Kinney Mfg. Div., The New York Air Brake Co.

42L **Ball Joints**
Up to 40° side flexibility with 360° rotating movement. For pressures to 7,500 lb./sq.in.; temperatures to 1000° F. Sizes ¼ in. to 12 in.
Barco Mfg. Co.

43R **Line Blind Valves**
Solid plate indicates permanent leakproof shut-off.
Hamer Valves, Inc.

45A **Rubber Cement Mixers**
Available in capacities from 5 to 500 gallons, jacketed or plain, of any weldable metal.
Struthers Wells Corp.

(Continued on back of this insert)

Please do not use this card after October, 1954

1	2	3	4	5	6	7	8	9	10	11	12	14	15
16	17	18	19	20	21	22	23	24	25	26	27	28	29
30	31	32	33	34	35	36	37	38	39	40	41	42	43
44	45	46	47	48	49	50	51	52	53	54	55	56	57
58	59	60	61	62	63	64	65	66	67	68	69	70	71
72	73	74	75	76	77	78	79	80	81	82	83	84	85
86	87	88	89	90	91	92	93	94	95	96	97	98	99
100	101	102	103	104	105	106	107	108	109	110	111	112	114
115	116	117	118	119	120	121	122	123	124	125	126	127	128

Advertisers' Products

IFC	3R	4A	6L	7A	8A	10L	11A	12A
13A	14L	15A	16A	17A	18A	19A	20A	21A
22A	23A	24L	24R	25A	26A	27R	28A	29R
30A	31A	32A	326A	38A	39A	41A	42L	43R
45A	46L	47A	48L	49A	50L	51A	52T	52B
53A	54A	59A	63A	65A	67A	68L	69R	71R
73R	74T	74B	75R	76T	76BL	76BR	77R	78T
78B	79R	80L	80TR	80BR	81T	81B	83R	84T
84B	85B	IBC	OBC					

Chemical Engineering Progress Data Service

Name .....

Position .....

Company .....

Address .....

City .....Zone .....State .....

☐ I want a subscription. Bill me $6.00 for a year.

July, 1954

PRODUCTS *(Continued)*

46L **Centrifugal Pumps**
Fabricated from chemically impervious graphite. Capacities from 25 to 250 gal./min.
Falls Industries, Inc.

47A **Plug Valves**
Sizes ½ in. thru 20 in. In all metals. Lever, gear, hydraulic, air or electric operated models.
DeZurik Shower Co.

48L **Vapor Recovery Systems**
Unit for venting volatile or inflammable liquid storage.
The Vapor Recovery Systems Co.

49A **Glassed Steel Reactors**
Feature the corrosion resistance of glass combined with the structural strength of steel. Delivered in a few days.
The Pfaudler Co.

50L **Heat Exchangers**
Special materials, designs. Shell and tube pressures up to 3,000 lb./sq.in. gauge. Shell and coil pressures in excess of 5,000 lb./sq.in. gauge.
Whitlock Mfg. Co.

51A **Graphite Anodes**
Caustic soda for the soap industry.
Great Lakes Carbon Corp., Electrode Div.

52T **Spray Nozzles**
Thousands of standard spray nozzles. Forty-eight page catalog.
Spraying Systems Co.

52B **Heat Exchangers**
"Conseco" designs, builds and installs heat exchangers for all process refinery and power plant applications.
Condenser Service & Engineering Co., Inc.

53A **Heat Transfer Medium**
High temperatures with low pressures made possible by this heat transfer medium.
The Dow Chemical Co.

54A **Cooling Towers**
Feature grid decks made from clear all heart redwood.
The Fluor Corp., Ltd.

59A **Spray Dryers**
Twenty-one recent Bowen spray dryer installations illustrated.
Bowen Engineering, Inc.

63A **"Super-D-Hydrators"**
For production of dry crystals.
The Sharples Corp.

65A **Liquid Filters**
Exclusive design, permits use of any medium in sheet form that can be crimped.
Dollinger Corp.

67A **Plant and Unit Design**
Electrical, mechanical, steam, power, hydraulic and structural engineering.
Badger Mfg. Co.

68L **Liquid Oxygen Pumps**
Vertical top-suction liquid oxygen pumps.
Lawrence Pumps, Inc.

69R **Centrifugally Cast Pipe**
O.D. ranging from 2½ in. to 24 in. and lengths up to 15 ft. according to diameter.
The Duraloy Co.

71R **Feeders**
Rates from a few drops to 60 gal./hr. Also force feed lubricators.
Manzel Division of Frontier Industries, Inc.

73R **Heat Exchangers**
Extended-surface heat exchangers. Design, research, engineering and production facilities.
Aerofin Corp.

74T **Water Filters**
Porous stainless steel elements, 0.2 to 1,000 gal./min. service.
Micro Metallic Corp.

74B **Stainless Steel Products**
Pipe, pails, pumps, rivets, scour cloths, sight flow glasses, taper pins, tubing, tubing fittings, ware, etc.
Schnitzer Alloy Products Co.

75R **Valves**
Gate, globe and swing check valves to meet material specifications.
Pacific Valves, Inc.

76T **Grinders, Crushers**
For small laboratory mills to high tonnage mills. Literature.
American Pulverizer Co.

76BL **Surface Temperature Thermometer**
For accurately measuring the temperature of any surface.
Pacific Transducer Corp.

76BR **Turbo-Dryers**
Continuous, vertical, and transfer types.
Wyssmont Co.

77R **Plastic Pumps**
For difficult corrosive solutions and abrasive slurries.
Vanton Pump & Equipment Corp.

78T **Metal Products**
Pilot plants and complete plants. Features vacuum rectifying column—with automatic air-operated control.
Artisan Metal Products, Inc.

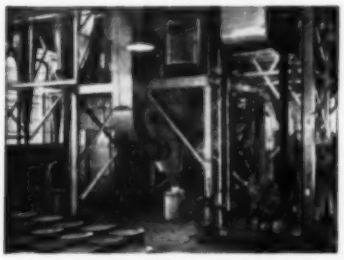
78B **Filter Presses**
For practically any kind of filter material.
D. R. Sperry & Co.

79R **Mixers**
Able to mix a wide range of formulations without lumping. Folder.
Paul O. Abbé, Inc.

80L **Silicone Defoamers**
Indicated to increase processing equipment capacity by eliminating space-wasting foam.
Dow Corning Corp.

80TR **Engineering Physics**
Facilities include a completely staffed Engineering Physics Section.
Foster D. Snell, Inc.

80BR **Steam Jet Ejectors**
Condensers and vacuum equipment. Corrosion resistant parts interchangeable with standard parts.
The Jet-Vac Corp.



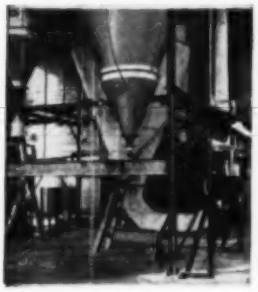
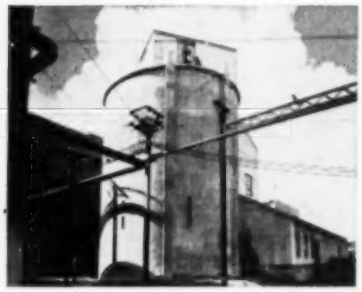
21 Recent Bowen Spray Dryer Installations that help prove the fact that

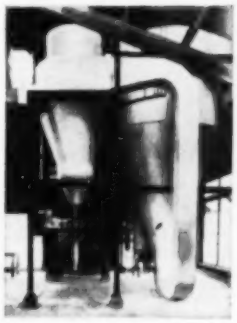
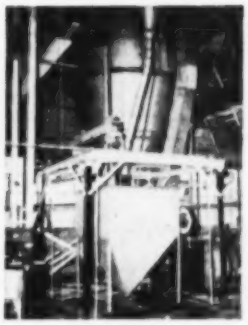
BOWEN SPRAY DRYERS

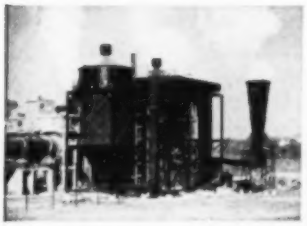
***Always* Offer You More!**

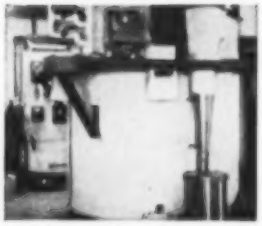
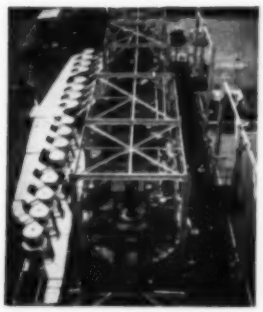
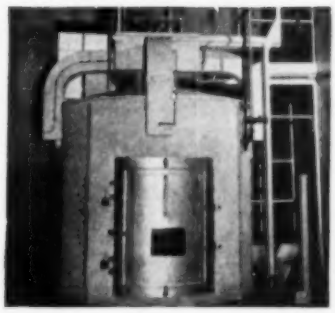
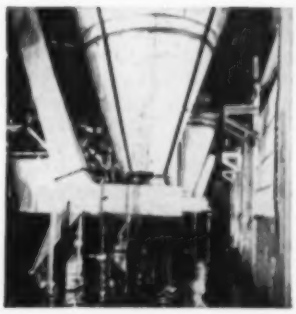
Write for illustrated booklet—
The Bowen Spray Dryer Laboratory

BOWEN ENGINEERING, INC.
NORTH BRANCH 13, N. J.



PRODUCTS (*Continued*)

817 **Corrosion-Resistant Mortars**
For acid- and alkali-proof masonry in floors, tanks, sewers, towers, etc.
Delrac Corp.

818 **Spray Nozzles**
For chemical spraying, cooling, humidifying, dehydrating, and other applications.
Binks Manufacturing Co.

83R **Dryers**
Double-shell semi-direct heat dryers, and double-shell indirect-heat dryers, etc. Also kilns and coolers.
Hardinge Co., Inc.

84T **Diaphragm Pumps**
Built of any material; pressures to 100 lb./sq.in. Rated capacity—1 to 90 gal./per.min.
T. Shriver & Co., Inc.

84B **Plasticizer Oil**
Compatibility with GRS, neoprene, and buna N type rubbers.
Pan American Refining Corp.

85B **Evactors**
Illustration shows two 4-stage evactors in pharmaceuticals plant. Also jet mixers, jet heaters, etc.
Croll-Reynolds Co., Inc.

IBC **Controlled Volume Pumps**
For process applications requiring inexpensive proportional feed.
Milton Roy Co.

OBC **Mixers**
Complete line of mixers. Speed reducer gears are protected by hollow-quill construction.
Mixing Equipment Co., Inc.

BULLETINS

1 **Quantometers.** Applied Research Laboratories quantometers for use in routine analytical production control problems employing optical emission principle. Features are versatility of design, range, precision, accuracy.

2 **Thermascrew.** Combined heat exchanger-conveyor, consisting of a hollow screw on a hollow shaft rotating in jacketed trough or pipe. For use in blanching, chilling, drying, mixing, solvent extraction of wide variety of products. Rietz Mfg. Co.

3 **Remote Pressure Measuring System.** ElectroSyn pressure detector, described in bulletin from Control Engineering Corp. System consists of suitable electrical source pressure detector (applied to vessel or pipe line without support) & indicating 250 degree meter mounted on control panel.

4 **Centrifugal Acid Pumps.** Illustrated brochure from A. R. Wilfley and Sons, Inc. on model AF pumps. Require no stuffing box, have no packing, no rubbing contact in operation, designed for 24-hr. service. Schematic drawings of each available model. More than 50 sizes & capacities.

5 **Heat Exchanger & Condenser Tubing.** Folder lists analyses & mechanical properties of 29 carbon, alloy & stainless tubing steels used in heat exchangers & condensers. Specification tables, application data, etc. Babcock & Wilcox Co.

6 **Pump Controls.** Automatic system for varying operation of pumps to satisfy fluctuating demands in large installations described & illustrated in Fischer & Porter Co. catalog. Principle of kinetic manometry used to actuate float with attached armature. Inductance change transposed electronically to an electric signal which stops or starts.

7 **Diffraction Gratings.** Loose-leaf binder monograph on diffraction gratings. Bausch & Lomb Optical Co. Lists 100 types & sizes of plan reflectance gratings, 20 of plane transmission gratings. Also considers special requirements.

8 **Vacuum Equipment.** Agitators, blenders, mixers, autoclaves, other process equipment available from J. P. Devine Mfg. Co., Inc. Brochure describes sizes & types available, lists specifications, auxiliary equipment. Engineering drawings & illustrations.

9 **HCl Absorbers.** Falls Industries, Inc. impervite graphite hydrogen chloride absorbers available in standardized sizes & types. Catalog describes units ranging from less than 500 lb./hr. to large falling film absorbers using a 36-in. tails tower with 241 long tubes of 12-ft. Schematic drawings & illustrations included.

10 **Pumps, Valves, Compressors, etc.** Information about special features, types, sizes & capacities of Worthington Corp. processing equipment contained in bulletin. Illustrations, drawings, details.

11 **Ammonia Plants.** A booklet dealing with yield & cost advantages, principal operating features, economics of unique design for M. W. Kellogg Co. ammonia plants. Includes design innovations, economic studies.

12 **Disc Feeder.** Model 50 Omega Machine Co. disc feeder for continuous & accurate feeding of dry materials at low rates. Feeding within ±3% by weight over 20:1 range; micrometer feed gate adjustment & illuminated scale; low filling height; visible feeding featured.

14 **Sewage & Sump Pumps.** Bulletin on three types of nonclog sewage & sump pumps available (vertical wet or dry pit, horizontal) from American-Marsh Pumps, Inc. Specifications, performance data, selection tables, diagrams, etc.

15 **Explosion-Proof Motors.** U. S. Electrical Motors, Inc. horizontal, totally enclosed, explosion-proof motors now available from ⅓ to 150 hp. Catalog.

16 **Pneumatic Weighing Scale.** Pneumatic platform scale adaptable for either batch weighing or continuous process control available from Weighing Components, Inc. Errors less than 0.25% of range. Illustrated & discussed in catalog 10.

17 **Vacuum Handbook.** Practical tips on installation, operation & maintenance of vacuum pumps & systems contained in handbook from F. J. Stokes Machine Co. Useful to those who install, operate, or service such equipment. Do's and don'ts for insuring long, trouble-free service life.

18 **Electric Pipeline Heaters.** General Electric Co. bulletin on application of electric heaters. Requirements, calculation, application, & other descriptive information, illustrations & chart of heat losses.

19 **Pipe Insulation.** Foamglas, a long-life, all-temperature pipe insulation for hot or cold piping, waterproofs & remains dry. No deterioration. −300° F. to +800° F. Leaflet from Pittsburgh Corning Corp. For pipe sizes ¼ through 36 in.

20 **Solids Processing Equipment.** Condensed presentation of B. F. Gump Co. line of processing equipment, including sifters, packers, mixers, grinders, etc. Each unit illustrated & described in detail, with specifications & engineering data.

21 **Indicating Recorder.** Thermo Electric Co., Inc. indicating recorder available both in potentiometer-pyrometer & resistance thermometer types. Binder insert section 60. Features are accuracy, sensitivity, durability, easy reading. Ranges from −100° F. to +100° F., & 0 to 3,000° F.

22 **Gilsulate Insulation.** Developed by American Gilsonite Co. For insulation & corrosion protection of hot, underground pipes. Three grades in temperature ranges from 200 to 520° F. May be applied by unskilled labor, economical & provides permanent protection. Bulletin.

23 **Automatic Boilers.** Orr & Sembower, Inc. packaged automatic boilers using variety of fuels. Sizes to 500 hp., pressures to 250 lb./sq.in. Economic to install, efficient, immediate response to load swings, other features. Illustrated bulletin.

24 **Centrifugal Extractor.** Super Centactor liquid-liquid counter-current centrifugal extractor for pilot plant use from Sharples Corp. Research Laboratories. Bulletin illustrates & describes new approach to countercurrent extraction, operational principle, etc.

25 **Electric d/p Cell Transmitters.** Technical information sheet from Foxboro Co. provides general information, pressure ranges, applications, schematic drawings on electric differential pressure cell transmitters.

26 **Motorized Valves & Control Motors.** Catalog 8203 from Minneapolis-Honeywell Regulator Co. Sections on specifications, types of motors & valves, tables, other pertinent information.

27 **Electric Circulation Heaters.** Typical applications & operating characteristics of Chromalox heaters featured in Edwin L. Wiegand Co. bulletin. Explains efficient, automatically controlled heating of liquids, gases, other heat-transfer media. Photos & drawings show installation methods & advantages of packaged units.

28 **Beryllium Copper Tubing.** Properties, applications & advantages of using seamless & Weldrawn beryllium copper tubing. Sheet No. 7-2 from Superior Tube Co. Mechanical & physical properties, welding & brazing method, corrosion resistance tables, other data.

29 **Heat-Recovery Equipment.** Graver water Conditioning Co. division of Graver Tank & Mfg. Co., Inc. bulletin covers saving boiler plant fuel & labor costs by use of continuous boiler blowoff heat recovery equipment. Data.

30 **Silent Chain Drives.** An 88-page book containing detailed engineering data, published by Link-Belt Co. Chains suitable for broad range of applications from tiny fractional hp. to huge drives. Combines flexibility and quietness of belt with positive action of gears.

31 **Acid-Proof Cement.** Revised bulletin with description of product, instructions for application of Robinson Clay Products Co. Staminite. For jointing ceramic forms.

32 **Photorecording.** 3rd Edition of Allen B. Du Mont Laboratories Inc. handbook on the techniques of photorecording and available equipment. Addition of section on the Polaroid-Land process as applied to oscillograph recording.

33 **Automatic Controls.** For applications requiring positive control of pressure, vacuum, temperature or liquid level, automatic controls equipped with sealed mercury contact switches. Mercoid Corp. illustrated bulletin gives additional data.

34 **Gas Conductivity Analyzer.** A relative thermal conductivity instrument for plant & laboratory fact finding & time saving. Illustrated bulletin lists available equipment. Also used for combustion & flue gas studies, purging, mixing, & wherever quantitative changes take place in gaseous mixtures. Gow-Mac Instrument Co.

EQUIPMENT

35 **Loading Vapor Recovery Unit.** For preventing loss of vapors from volatile liquids during loading tank cars & trucks, Vernon Tool Co. Greenwood vapor recovery unit consists of conical-shaped aluminum housing, sealing ring, transparent Plexiglas cover and connection for vapor recovery hose. Permits observation during filling.

36 **Water Purity Safeguard.** Ventgard, a product of Barnstead Still & Sterilizer Co. permits storage of distilled water without air-borne contamination, either solid or gaseous.

37 **Pipeline Regulators.** Series 8900 Air Reduction Co., Inc. regulators. Designed for use with gases supplied by low-pressure pipeline systems. Maintain steady gas pressure eliminating need for adjustment. Cataolg.

38 **Plastic Tubing.** Ace-Flex transparent plastic tubing is inert, odorless, nontoxic, & ages well. Resistant to most inorganic acids & alkalies, also many organic chemicals. May be steam sterilized. American Hard Rubber Co.

39 **Canned Centrifugal Pump.** Dynapump magnetically driven centrifugal pumps described in Fostoria Pressed Steel Corp. bulletin. Motor & pump in one sealed unit, no need for stuffing box. Stainless steel, for pumping most fluids. Provides leakproof unit which eliminates 90% of usual difficulties.

40 **Geared Motors.** Complete line of geared motors manufactured in accordance with NEMA specifications. Being introduced to U. S. market by Belgian Electric Sales Corp. Catalog illustrates types, gives full data. Sizes 1/3 to 15 hp.

41 **Air Filter.** Roll-O-Matic automatic self-cleaning glass-fiber filter for industrial ventilating & air conditioning systems. Large dust holding capacity. American Air Filter Co., Inc.

42 **Gas Mask Cannister Cart.** Binder insert chart containing comprehensive list of 433 gases, fumes, mists & dusts, together with Acme cannister recommended for each hazard. Acme Protection Equipment Co.

43 **Steam Trap.** Addition to line of Armstrong Machine Works integral strainer steam traps is larger model No. 882. Capacities 1,300 to 2,200 lb./(condensate) (hr.). Maximum pressure 250 lb./sq.in. gauge.

44 **Platinum-Resistance Thermometers.** American Instrument Co., Inc. High precision & accuracy. Range −183° C. to +500° C. Pyrex stems 18 in. to as short as 5½ in. custom made. Leaflet gives details.

45 **Ultrasonic Viscometer.** Featuring a rugged, strong, sensitive probe without moving parts, new ultrasonic viscometer from Ultrasonic Engineering Co. Simple & rapid

measurements made by immersion of sensing element of probe in any liquid. Panel meter. Range from 0 to 100,000 centipoises or higher.

46 **Temperature Recorder.** Sturdy temperature recorder Model 1000 with 6 in. clear-reading, evenly calibrated chart from Electric Auto-Lite Co. Available with 24-hr. or seven-day electric or mechanical chart drive.

47 **Tapes & Dispensers.** Six-page folder from Minnesota Mining and Mfg. Co. discusses how segments of chemical industry can use Scotch brand pressure-sensitive tapes & dispensers to speed production & reduce costs. Covers cellophane acetate fibre, masking, plastic, other tapes.

48 **Electrophoresis Apparatus.** Several improvements announced by Perkin-Elmer Corp., including Land cameras, are incorporated in Model 38-A electro-phoresis apparatus. Easily operated, completely portable, operates from top of table, dimensions 65 in. x 16 in. x 20 in. Used for separating complex protein & colloid mixtures.

49 **Portable Potentiometer.** Improved flexibility for checking & calibrating temperature measurement & control instruments offered in series 300 portable potentiometer by Wheelco Instruments division of Barber-Colman Co.

50 **Mixing Pumps.** Graymills Corp. catalog of pumps for agitating & pumping liquids carrying solids content which must be mixed or kept in suspension. Sizes range from 2 to 40 gal. Handle liquids with high abrasive content without binding or harmful wear because no bearings, seals or packings are below liquid level. Special impeller design & patented agitation features.

51 **Thermowells.** Trinity Equipment Corp. Double-bore Thermowells minimize factors of error in temperature instrument test procedures. Eliminate need of separate test well. Available in all standard materials. Seven standard lengths from 4½ to 18 in. Special lengths are made.

52 **Solenoid Valves.** Two new variations of 2-way bronze & brass body solenoid valves announced by Automatic Switch Co. make them suitable for handling corrosive gases & liquids, also steam to 450° F. Packless types; easily disassembled for cleanings. Bulletin gives other information & drawings.

53 **Gas Analyzers.** Portable compact effective analyzer for use in garages, mines, factories, chemical plants, etc. Safeguards against hazard of odorless, colorless carbon monoxide. Also a continuous hydrogen analyzer announced by Taller & Cooper, Inc. Folders on each show operation, list features.

54 **Ceramic Fibers.** Leaflet from Carborundum Co. refractories division announces Fiberfrax, a fiber of aluminum-silicate. Blown weight 2 lb./cu.ft. Easily compressed. Little loss of properties at 2,300° F. Will not melt under 300° F. Information on availability, electrical characteristics, use as filter media, or thermal insulation, etc.

55 **Turbo Pumps.** J. S. Coffin, Jr., Co. type DE turbo pumps illustrated & described in folder. Typical services are boiler feed, water injection, oil refinery charge, & others.

56 **Pressure Regulator.** Now available from Paulsen-Johnson Co. a ¾ in. size, low-pressure, demand-type, air & gas regulator. Passes to 600 cu.ft./hr. 0.6 sp.gr. gas at 4 in. WC to 5 lb./sq.in. gauge. Soft seats assure positive shutoff with accuracy. For use wherever low pressures must be maintained.

57 **Flow Meter.** Leaflet from Fischer & Porter Co. describes an integrating flow meter said to effect economies in batch processing. Schematic diagram of system with pertinent information concerning detailed experiences in several industries.

58 **Aluminum Dust-Tite Valve.** Announced by General Machine Co. a specially treated aluminum self-cleaning dust-tite valve for blenders, pipeline feeders, etc. Features same metal-to-metal, spherical shear-type opening & closing mechanism as other Gemco valves. Sizes from 3 to 20 in.

59 **High Pressure Valves.** Added to line of valves by Annin Co. series 34 for pressures to 6,000 lb./sq.in. & temperatures to 900° F. Sizes ½ & ¾ in. in variety of body & trim materials, in offset globe & angle bodies.

60 **Weather-Proof Jacketing.** Bulletin from Childers Mfg. Co. on aluminum weather-proof jacketing for insulated lines. Easily installed, requires no painting. Details in illustrated bulletin.

61 **Compressor.** From Read Standard Corp. leaflet on Standardaire blower said to have high efficiency, to be engineered compactly, handle gas or air, & is adaptable for pressure or vacuum service. Single units for low or medium pressures; multiple units for pressures to 100 lb./sq.in gauge. Specifications, cutaway views, selection charts.

62 **Laboratory Ovens.** Bulletin from Despatch Oven Co. fully illustrated on laboratory & production ovens. Covers various types with details on each plus much other pertinent data.

63 **Electrical Protection.** Multi-Amp from Multi-Amp Corp. & distributed by Westinghouse Electric Supply Co. a portable, high-current test instrument for testing & calibrating current transformers, meters, oil circuit breakers or reclosers. Bulletin gives illustrations, general description, other required information.

64 **Processing Vessels.** Bethlehem Foundry & Machine Co. processing vessels illustrated in new leaflet. Designed for use in reaction, agitation, heat transfer, distillation, drying, sublimation, crystallization & drying. Consideration given to corrosion problems, abrasion & erosion, high temperatures in both special or standard design equipment.

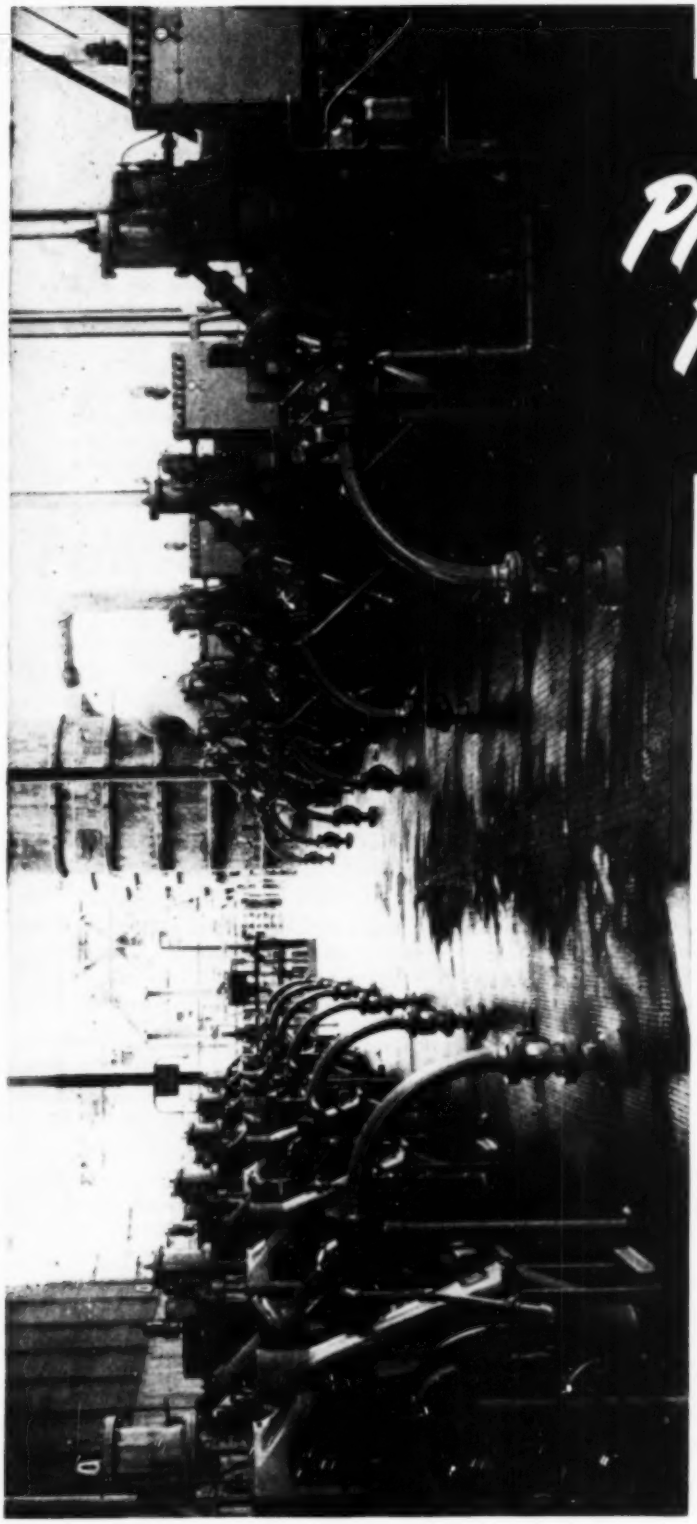
CHEMICALS

65 **Flexol Plasticizer 77-G.** Benzoate plasticizer available in tank-car quantities from Carbide and Carbon Chemicals Co. High solvent power with polyvinyl chloride, acetate, butyral; ethyl cellulose, polystyrene & others. Promotes rapid fluxing of calendering & extrusion resins, & acts as fusion aid in organosols & plastisols.

66 **Peracetic Acid.** Reprint available from Buffalo Electro-Chemical Co., Inc. division of Food Machinery and Chemical Corp. on how Becco peracetic acid 40% may be used for bleaching nylon type 670. Bleach bath formula, make-up & procedure for cold or jig bleaching, plus knit-goods bleaching on nylon types 670 & 200 explained in detail.

67 **Silicone Finish.** Dow Corning Corp. emulsion 105 applied to synthetic or woolen fabrics imparts durable water repellency, also good resistance to staining. Does not alter appearance, color or porosity. Binder insert available.

(More Data on page 64)



12 PRODUCTIVE REASONS why

SHARPLES SUPER-D-HYDRATORS mean low cost PRODUCTION of DRY CRYSTALS

This battery of twelve C-27 Super-D-Hydrators installed in one of the world's most modern caustic plants, is handling the difficult job of separating sodium chloride from caustic liquor. High efficiency rinsing and drying are primary requisites in this operation.

SHARPLES

THE SHARPLES CORPORATION
2300 WESTMORELAND STREET
PHILADELPHIA 40, PA.

NEW YORK • PITTSBURGH • CLEVELAND • DETROIT • CHICAGO
NEW ORLEANS • SEATTLE • LOS ANGELES • SAN FRANCISCO • HOUSTON

Associated Companies and Representatives throughout the World

DATA SERVICE

(Continued from page 62)

68 **Vinsol Resin.** Revised technical booklet from Hercules Powder Co. on Vinsol resin. Gives current information on use as an extender & reveals uses. Sections on aldehyde condensates; solvent-blended phenolic resins, water-blended phenolic resins, & phenol-formaldehyde copolymers.

69 **Aerosol Paint Remover.** Du Pont Co. announces formula which produces foaming action said to be faster, cleaner, more active than brush-applied types. Effective with enamels & nitrocellulose lacquers. Greatest advantage is use in varnish removal. Bulletin.

70 **Uses of Ethanolamines.** Published by Jefferson Chemical Co. bulletin on methanolamine, diethanolamine, triethanolamine presenting physical, toxicological & chemical properties, specifications, analysis, uses, handling & storage information. Lists 381 references on physical properties & chemistry.

71 **Oleic Acid.** Production of new highly distilled fractionated fatty acid oleic acid No. 905 announced by Swift & Co. For use where high acid number, low titer & color clarity desired. Good stability. Formula & other information available.

72 (72) Cato starch, a pulp headbox additive from National
73 Starch Products, said to improve strength factors such as mullen, fold, tensile, pick, etc. at low concentrations on various pulps. (73) Story of Starches, semi-technical booklet presents story of starches, creation of new varieties, handling, other interesting & pertinent information.

74 **Gelling Agent.** National Lead Co. Ben-A-Gel for all types of aqueous system. Material is highly beneficiated hydrous magnesium silicate of milky-white color, used to thicken water solutions or emulsions such as lotions, etc. Unaffected by heat or aging.

75 **Plasticizers.** (75) Technical bulletin from Monsanto Chemi-
76 cal Co. on Di (n-Octyl, n-Decyl) phthalate (DNODP) a primary plasticizer said to impart low volatility, good flexibility to finished compositions. Compatible with many resins such as polyvinyl chloride, ethylcellulose, polystyrene & others. (76) Di(2-Ethylhexyl) Adipate (DOA) also a primary plasticizer which imparts low-temperature flexibility to polyvinyl chloride resins & synthetic rubbers. Bulletins give much other information on both.

77 **Catalog & Wall Chart.** Just issued, specification catalog & price list No. 54 on J. T. Baker Chemical Co. reagents & other chemicals. Also small wall chart on composition of concentrated reagent acids & ammonium hydroxide.

78 **Morpholine.** A hydrocarbon derivative for use in agriculture to Zymurgy fields. Industrial uses described in detail in technical bulletin from Jefferson Chemical Co. A colorless, hygroscopic liquid with amine-like odor. Solvent power said to exceed that of benzene, pyridine & dioxane. Completely miscible with organic solvents for dissolution of resins, dyes, waxes, shellac.

79 **Diphenylamine.** An ultra-pure grade, in white, solid form. Said to yield almost colorless solutions in concentrated sulfuric acid, with resulting low blanks. For use in precision spectro-photometric analysis of nitrate in many materials. Detects chromium, iron manganese, uranium zinc. Fisher Scientific Co.

80 **Textile Chemical Agents.** From Dexter Chemical Corp., two new agents for improvement of fastness of dyestuffs on acetate, cotton & rayon fabrics. Dextrol Antifume A-15 being sold as permanent gas fading inhibitor for dyed acetate fabrics. Detrafix B fixative for direct dyes on cotton & rayon. Said to prevent migration & staining with prints. Renders most dyes fast against mild soap washing.

81 **Catalyst.** For removal of hydrogen sulphide from a gas or air stream, new catalyst from Davis Emergency Equipment Co. Basis is activated carbon treated with metal oxides such as vanadium, copper, iron, chromium. Efficient at room temperatures even when oxygen content of gas stream drops to 1.5%. Bulletin.

82 Aerosol Surface Active Agents.—AERO Dicyandiamide
83 Booklet from American Cyanamid Co. contains discussion of surface chemistry, facts about grades now available & toxicity data. (83) Booklet on physical & chemical properties of Aero Didyandiamide & its applications. Important use is synthesis of organic chemicals & in manufacture of resins, dyestuffs, antioxidants, etc.

84 **Polyamide Resins.** Technical bulletins 11-1-1 & 11-4-1 from General Mills Inc. No. 11-1-1 on polyamide resins 90, 93, 94, 95, 100. Formulae grade, other data. No. 11-41 polyamide resin 100—epoxy resin thermosetting compositions. Includes preparation of blends, curing time, properties, other details.

85 **Ultraviolet Absorbers.** From Antara Chemicals, division of General Aniline and Film Corp. booklet describing Uvinul 400 & 490 ultroviolet absorbers. Suggested as means of control of radiation effects within ultraviolet range either as protective coating or for incorporation in materials such as lacquers, plasticized cellulose acetate, sunglasses, eyeshields or filters, to preserve eye sensitivity.

86 **Antioxidant & Styrene Monomer.** (86) Technical & non-
87 technical suggested uses of Koppers Co., Inc. "dbpc antioxidant" contained in two new bulletins. C-4-115 furnishes toxicological information, description of chemical reactions; C-4-197 information in nontechnical language. (87) Description of Koppers styrene monomer & uses contained in bulletin. Obtained from this basic chemical & its applications include synthetic rubber, polystyrene, ion-exchange resins, & long list of others.

88 **Fumaric Acid & Flattening Agent.** (88) Bulletin from
89 Monsanto Chemical Co. on use of fumaric acid to improve alkyd resins, polyester resins, tall oil varnishes, other materials. Processing logs, other data. (89) Easily dispersable flattening agent requiring little or no grinding when added to varnish or lacquer formulations. Called Santocel 54, is available in 20-lb. bags in production quantities.

90 **Low-Density Silica Gel.** Free-Flowing white powder weighing 4.5 lb./cu.ft., low-density silica gel from Davison Chemical Corp. Particles of Syloid 244 predominantly below 1μ. Good oil absorption capacity of 240 lb./100 lb. silicon dioxide. When mixed it becomes transparent & remains in suspension indefinitely in most organic solvents.

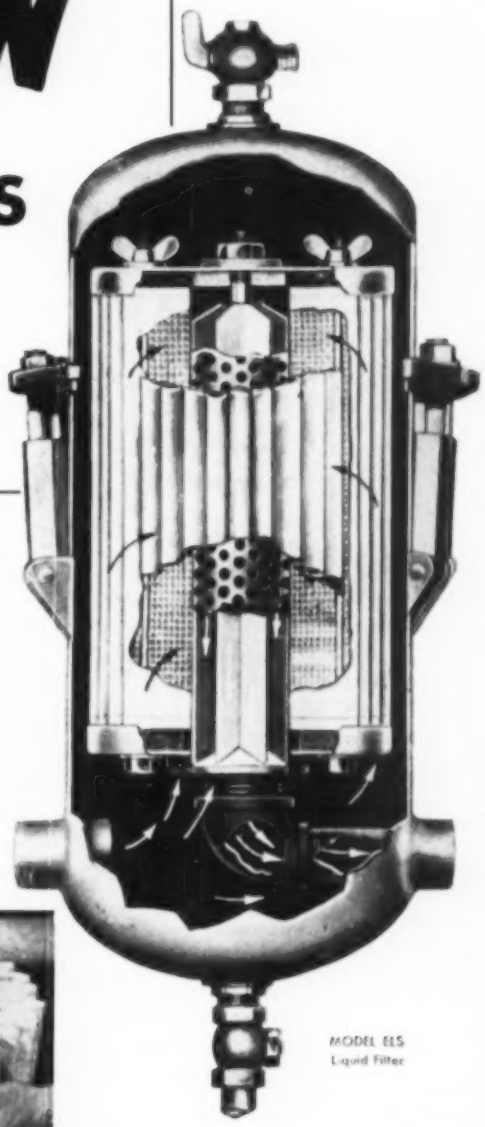
91 **Cracking Catalyst.** From American Cyanamid Co. announcement of three new grades of microspheroidal fluid cracking catalyst now available. Aerocat MS catalyst designated grade 50/60 (light); grade 60/70 (intermediate; grade 75/85 (narrow). Said to insure greater efficiency over wide range of industry's fluid catalytic cracking unit thus achieving better catalyst utilization.

LET

STAYNEW

LIQUID FILTERS

Solve Your Filtration Problems!



MODEL ELS
Liquid Filter

Bring your liquid filtration problems to Dollinger engineers. Their specialized experience is available in recommending the most efficient and economical equipment for filtering liquids in a wide range of viscosities, temperatures, acidities, alkalinities, pressures and capacities.

Staynew exclusive design, permits use of *any medium in sheet form that can be crimped.* Metal, plastic, fabric, ceramic and metallic mesh media can be used for super-fine filtration.

Write us today outlining your specific liquid filtration problem. From our 30 years experience in liquid filtration, we have built up a vast file of helpful information. Any part of this information is yours for the asking—no obligation.

Staynew Radial Fin Construction provides the largest possible filtering area for available space. Slip-On Insert—exclusive in Staynew Filters—permits simple, inexpensive cleaning or replacement of media.

Representatives in Principal Cities

DOLLINGER MFG. PROTECTOMOTOR PAT. APP'D FOR STAYNEW FILTERS

DOLLINGER

CORPORATION

79 Centre Pk., Rochester 3, N. Y.

ALL TYPES OF FILTERS FOR EVERY INDUSTRIAL NEED

AUDITOR'S REPORT

We have examined the balance sheet of the American Institute of Chemical Engineers as of December 31, 1953, and the related statement of income and surplus for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, the accompanying balance sheet and statement of income and surplus present fairly the financial position of the American Institute of Chemical Engineers at December 31, 1953, and the results of its operations for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

F. W. LAFRENTZ & CO.
Certified Public Accountants

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

BALANCE SHEET

DECEMBER 31, 1953

Assets

Current Assets:		
Cash on hand and demand deposits	$130,356.12	
Cash in savings banks	99,498.09	$229,854.21
Investments, at cost including accrued interest		84,322.39
Accounts receivable, net		21,470.43
Inventory, at cost		13,767.89
Total current assets		$349,414.92
Deposits at Airlines and Post Office		$ 1,791.29
Furniture and Fixtures, at cost—less reserve for depreciation		12,089.99
Total		$363,296.20
Trust and Special Funds:		
Cash in banks	$72,994.61	
Investments, at cost	8,296.25	$ 81,290.86
Total		$444,587.06

Liabilities

Current Liabilities:		
Accounts payable		$ 8,352.49
Total current liabilities		$ 8,352.49
Deferred income		114,895.79
Reserves:		
Education, Student Meetings and Preprint Funds	$ 4,648.67	
Publication program	42,182.70	46,831.37
Surplus		193,216.55
Total		$363,296.20
Trust and Special Funds:		
Albert E. Marshall Fund	$ 3,000.00	
Research Committee Fund	78,290.86	81,290.86
Total		$444,587.06

STATEMENT OF INCOME AND SURPLUS

FOR THE YEAR ENDED DECEMBER 31, 1953

Income:		
Membership dues	$192,524.01	
Less allocation to subscriptions at annual rate of $4.50 per member	59,706.75	$132,817.26
Membership entrance fees		14,762.00
Publication income		284,668.48
Meetings income		3,734.66
Income on investments		3,526.85
Sundry income		147.00
Total income		$439,656.25
Expenses:		
Publication expenses	$149,926.54	
Salaries and commissions	168,767.52	
Employees' Retirement Plan	5,118.63	
Federal Insurance Contributions	1,595.65	
Printed material, stationery, postage, Telephone & Telegraph	24,831.49	
Meetings expenses, travel, etc.	17,340.63	
Rent and electricity	13,165.05	
Awards	1,762.31	
Provision for depreciation—Furn. & Fixtures	5,932.67	
Provision for doubtful account—Dues	2,839.41	
Miscellaneous	6,267.23	$397,547.13
Other Expenses:		
Participations in professional groups	$ 3,076.00	
Committee expenses	6,460.74	9,536.74
Total expenses		$407,083.87
Net income for year		$ 32,572.38
Surplus, January 1, 1953		156,261.05
Total		$188,833.43
Add reserve for Publication Program	$ 55,000.00	
Less net expenditures to December 31, 1952	8,257.55	46,742.45
Total		$235,575.88
Deduct sundry charge to surplus, net		176.63
Total		$235,399.25
Deduct reserve for publication program	$ 55,000.00	
Less net expenditures to December 31, 1953	12,817.30	42,182.70
Surplus, December 31, 1953		$193,216.55

STAFFED TO HANDLE MAJOR PROJECTS

EXPERIENCED IN THE FOLLOWING:

WORKING WITH our process engineers on all projects, both plant and unit design, are staff engineers well versed in specialized phases of engineering such as electrical, mechanical, steam, power, hydraulic and structural.

Perhaps our service will be just what you are looking for—a service responsible for the design and construction of your complete plant or unit project. What you are looking for in size... integrated experiences... flexibility... and broad knowledge of processing!

Photograph shows recently completed naphthalene unit

Engineering

Design and Construction of Process Plants

●

Design and Construction of Process Units

●

Process Evaluations

●

Economic Studies

Organic Chemical Synthesis

Inorganic Chemical Processing

Catalytic Operations

Solvent purification

Separation and Refining of Organic Chemical Mixtures by conventional, azeotropic and extractive distillation, liquid-liquid extraction, crystallization

Petroleum Processing:
Topping and Vacuum Distillation
Lube Oil Units

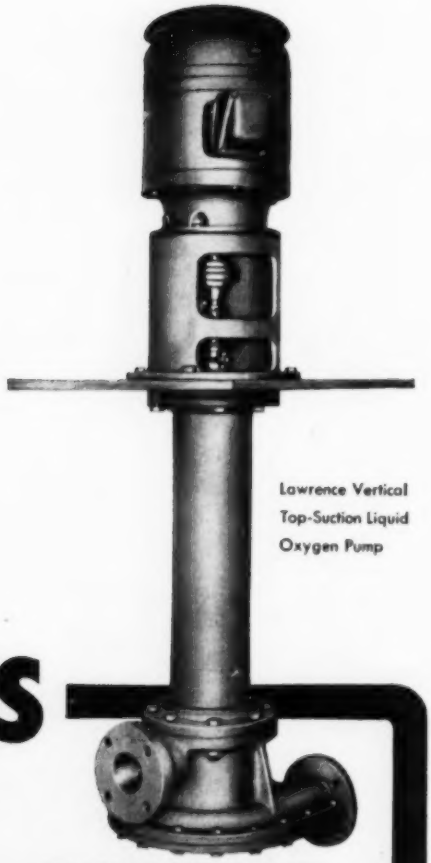
Coal Tar Distillation

Gas and Vapor Recovery

Pharmaceuticals

BADGER MANUFACTURING COMPANY

230 BENT STREET, CAMBRIDGE 41, MASS. • 60 EAST 42nd STREET, NEW YORK 17, N. Y.



Lawrence Vertical Top-Suction Liquid Oxygen Pump

PUMPS to handle LIQUID OXYGEN

At —297.4° F. — the boiling point of liquid oxygen — many abnormal factors must be considered in designing a centrifugal pump. Metals become brittle . . . packing will freeze solid . . . the net positive suction head is usually very low, so that the liquid is at or near its boiling point. All of these difficulties are successfully overcome in Lawrence Vertical Top-Suction liquid oxygen pumps.

Lawrence construction employs metals not affected by the extreme low temperature and locates the packing far enough above the liquid so that it is exposed only to the oxygen vapors and functions normally. Location of the suction on top prevents vapor binding, even at boiling point.

If your problem involves pumping a liquefied gas at extreme low temperature, write us the pertinent details. No obligation.

Write for Bulletin 203-6 for summary of acid and chemical pump data.

LAWRENCE PUMPS INC.

371 MARKET STREET, LAWRENCE, MASS.

CANDIDATES

(Continued from page 52)

Iwata, Harry M., *Baltimore, Md.*
Jefts, Albert W., *Glenville, Conn.*
Jordan, Harry E., *Port Washington, N. Y.*
Keselik, John, *Lake Jackson, Tex.*
Kosko, J. W., *Tallmadge, Ohio*
Lamb, Robert H., *Darien, Conn.*
Leet, Harold A., *Elkton, Va.*
Leppla, P. W., *Palos Verdes Estates, Calif.*
Lio, S. P., *Mexico, D. F., Mexico*
Longwell, Paul A., *China Lake, Calif.*
Maligrave, Fred J., *Santa Fe Springs, Calif.*
McCarthy, Eugene L., *Oklahoma City, Okla.*
McIntire, O. R., *Midland, Mich.*
Middlebrook, George B., *E. Aurora, N. Y.*
Morin, William C., *Rochester, N. Y.*
Neiman, Paul E., *Summit, N. J.*
Neimeyer, G. O., *London, England*
O'Kane, Robert G., *Belchertown, Mass.*
O'Keefe, Eugene W., *Niagara Falls, N. Y.*
Outterson, Charles R., *Richmond, Va.*
Polis, John E., *Wayland, Mass.*
Powers, John R., *Keystone Heights, Fla.*
Pruitt, Norman W., *Kansas City, Mo.*
Quillen, Charles S., *E. Orange, N. J.*
Richardson, Paul A., *Pittsburgh, Pa.*
Rorso, Ole, *Larchmont, N. Y.*
Scheline, Donald C., *Pittsburgh, Pa.*
Stevenson, Charles E., *Idaho Falls, Idaho*
Thomas, Jeremiah L., Jr., *Chattanooga, Tenn.*
Vener, Raymond E., *Drexel Hill, Pa.*

Applicants for Associate Membership

Furbee, Jack, *Baytown, Tex.*
Graham, Burton W., *Baltimore, Md.*
Guidi, Raymond A. A., *Crystal Lake, Ill.*
Morehouse, David W., *Mulberry, Fla.*

Applicants for Junior Membership

Bahn, E. Lawrence, Jr., *Wolf Lake, Ill.*
Barthenheier, Fred, *Louisville, Ky.*
Berry, Lauren R., *Harvey, Ill.*
Blackman, N. Martin, *Stamford, Conn.*
Boeglin, Albert F., *Idaho Falls, Idaho*
Carroll, Robert Frank, *Avon Lake, Ohio*
Currie, J. Greg, *Nova Scotia, Canada*
Davidson, John K., *Schenectady, N. Y.*
deChazal, Marc, *Columbia, Mo.*
Driscoll, David G., *Buffalo, N. Y.*
Edwards, R. C., Jr., *Burlington, Iowa*
Ferrell, R. D., *New Orleans, La.*
Fischer, Reinhold, *Charleston, W. Va.*
Foreman, Thomas A., *Boyertown, Pa.*
Galegar, Robert Roy, *Ponca City, Okla.*
Gallagher, William R., *Grand River, Ohio*
Graham, Walter L., *Pampa, Tex.*
Grosso, Charles Anthony, *New Rochelle, N. Y.*
Guardia, Javier, *Panama City, Panama*
Gugler, Clark L., *Lawrence, Kans.*
Halle, Mitchell J., *Waltham, Mass.*
Hersman, Ferd W., *Cincinnati, Ohio*
Holgate, Arthur E., *East Paterson, N. J.*
Homme, Arthur C., *Lynbrook, L. I., N. Y.*

Horton, John G., *Wilmington, Del.*
Hwu, Chung-Kong, *Cincinnati, Ohio*
Kohn, James Paul, *Lawrence, Kans.*
Luckenbach, E. C., *Cranford, N. J.*
Maloney, Owen C., *Joliet, Ill.*
May, James B., *Decatur, Ill.*
Mraz, James A., *Westlake, Ohio*
Mullen, James William, *Watervliet, N. Y.*
Mullowney, James F., Sr., *Whittier, Calif.*
Nessler, Phillip J., *Texas City, Tex.*
Plyler, James I., *Wilmington, Del.*
Poe, Alfred, *New York, N. Y.*
Rathmell, Richard K., *Crown Point, Ind.*
Raviv, Abraham, *Haifa, Israel*
Reid, James B., *St. Albans, W. Va.*
Richards, J. W., *Orange, Tex.*
Rogers, C. E., *Charleston, W. Va.*
Rosenfeld, Alan S., *Portland, Ore.*
Rutledge, Gene P., *Oak Ridge, Tenn.*
Schaefer, Robert L., *Midland, Mich.*
Schmid, Bruce K., *Pittsburgh, Pa.*
Schmidt, Harold W., *Cuyahoga Falls, Ohio*
Schneider, Kenneth J., *Richland, Wash.*
Schulte, Thomas O., *Houston, Tex.*
Shamiyeh, Issa H., *Detroit, Mich.*
Sill, Alvin J., *Buffalo, N. Y.*
Stassfort, Derrick H., *Calumet City, Ill.*
Waldrop, Neal A., *Detroit, Mich.*
Wilderoter, Stanley B., *San Martino DiTrecate, Italy*
Yuan, Wei, *St. Louis, Mo.*
Zimmerman, John O., *Dunbar, W. Va.*

CHEMICAL ENGINEERING HEADS N.S.F. GRANTS

Of the seventeen grants for basic research in the engineering sciences recently awarded by the National Science Foundation, seven were in chemical engineering. Mechanical and metallurgical engineering departments received three each; civil engineering, two; and mining and electrical engineering, one apiece.

The chemical engineering awards went to J. W. Westwater, University of Illinois, for work on metastable boiling, $13,500; James O. Osburn, State University of Iowa, for supersaturation in liquid solutions, $8,000; Harold E. Hoelscher, Johns Hopkins University, for kinetics of reactions in three-phase systems, $9,000; Robert E. Treybal, New York University, for mass transfer to and from solid spheres immersed in a flowing fluid, $7,000; Wayne R. Kube, University of North Dakota, sorption of water vapor by thermally treated lignite, $3,400; George Thodos, Northwestern University, vapor liquid equilibrium studies in multicomponent systems, $10,000; E. W. Comings, Purdue University, properties of gases at high pressures, $14,000.

Other grants will be announced later in the year.

Centrifugal castings are superior castings. The metal is sounder, finer-grained, more uniform. It is free of gas pockets, blow holes and other defects often difficult to keep out of static castings. Tensile strength is close to that of rolled or hot-forged alloy steel. Dimensions are accurate, usually requiring less machining and finishing and thus speeding production.

If you require *extra* qualities in your high alloy pipe, investigate DURASPUN Centrifugally Cast Pipe. We can produce it in OD ranging from 2½" to 24" and in lengths up to 15' according to diameter. Our experience in the field of centrifugal high alloy castings dates back to 1931. Our experience in the field of static high alloy casting goes back to 1922. We can give you good service.

THE DURALOY COMPANY
Office and Plant Scottdale, Pa. • Eastern Office 12 East 41st Street, New York 17, N.Y.

FUTURE MEETINGS and Symposia of the Institute

MEETINGS **SYMPOSIA**

Glenwood Springs, Colo., Hotel Colorado, Sept. 12-15, 1954.

TECHNICAL PROGRAM CHAIRMAN: Dr. Charles H. Prien, Head, Chem. Div., Denver Res. Inst., Univ. of Denver, Denver 10, Colo.

Agglomeration

CHAIRMAN: A. P. Weber, International Engineering, Inc., 15 Park Row, New York, N. Y.

Uranium Processing and Refining

CHAIRMAN: R. H. Long, Vitro Eng. Div., Vitro Corp., 120 Wall St., New York, N. Y.

Oil Shale and Shale Oil Processing

CHAIRMAN: W. I. R. Murphy, Pet. & Oil Shale Exp. Station, U. S. Bureau of Mines, P. O. Box 621, Laramie, Wyoming.

DEADLINE PAST

Annual—New York, N. Y., Statler Hotel, Dec. 12-15, 1954.

TECHNICAL PROGRAM CHAIRMAN: G. T. Skaperdas, Assoc. Dir., Chem. Eng. Dept., M. W. Kellogg Co., 225 Broadway, N. Y. 7, N. Y.

ASST. CHAIRMAN: N. Morash, Titanium Div., National Lead Co., P. O. Box 58, South Amboy, N. J.

Reaction Kinetics

CHAIRMAN: N. R. Amundson, Dept. of Chem. Eng., Univ. of Minnesota, Minneapolis 14, Minn.

Gas Absorption

CHAIRMAN: R. L. Pigford, Div. of Chem. Eng., Univ. of Delaware, Newark, Del.

Solvent Extraction

CHAIRMAN: Dr. R. B. Beckmann, Dept. Chem. Eng., Carnegie Inst. of Tech., Schenley Park, Pittsburgh 13, Pa.

New Processes Utilizing Moving Beds

CHAIRMAN: N. Morash, Tit. Div., National Lead Co., P. O. Box 58, South Amboy, N. J.

Biochemical Engineering

CHAIRMAN: C. W. Weil, Chas. Pfizer & Co., 11 Bartlett St., Brooklyn 6, N. Y.

DEADLINE—August 12, 1954

Louisville, Ky., Kentucky Hotel, March 20-23, 1955.

TECHNICAL PROGRAM CHAIRMAN: R. M. Reed, Tech. Dir., Gas Proc. Div., The Girdler Corp., Louisville 1, Ky.

Heat Transfer

CHAIRMAN: R. L. Pigford, Div. of Chem. Eng., Univ. of Delaware, Newark, Del.

DEADLINE—November 20, 1954

Houston, Texas, Shamrock Hotel, May 1-4, 1955.

TECHNICAL PROGRAM CHAIRMAN: J. L. Franklin, Res. Assoc., Humble Oil & Refining Co., P. O. Box 1111, Baytown, Texas.

Nucleation Processes

CHAIRMAN: D. W. Oakley, Plant Mgr., Metal & Thermit Corp., 1 Union St., Carteret, N. J.

MEETINGS **SYMPOSIA**

Flow of Fluids Through Porous Media

CHAIRMAN: H. Dayton Wilde, Mgr. Res. Div., Humble Oil & Ref. Co., Box 2180, Houston 1, Tex.

Azeotropic and Extractive Distillation

CHAIRMAN: Dr. D. E. Holcomb, Dean of Eng., Texas Technological College, Lubbock, Tex.

DEADLINE—January 1, 1955

Lake Placid, N. Y., Lake Placid Club, Sept. 25-28, 1955.

TECHNICAL PROGRAM CHAIRMAN: L. J. Coulthurst, Chief Proc. Designer, Foster Wheeler Corp., 165 Broadway, New York 6, N. Y.

DEADLINE—May 25, 1955

Annual—Detroit, Mich.—Statler Hotel, Nov. 27-30, 1955.

TECHNICAL PROGRAM CHAIRMAN: T. J. Carron, Supervisor, Chem. Eng. Section, Ethyl Corp., Res. Labs., 1600 West Eight Mile Road, Detroit 20, Mich.

Photochemical Processes

CHAIRMAN: Prof. J. J. Martin, Dept. Chem. Eng., Univ. of Michigan, Ann Arbor, Mich.

DEADLINE—July 27, 1955

Los Angeles, Calif., Statler Hotel, Feb. 26-29, 1956.

TECHNICAL PROGRAM CHAIRMAN: T. Weaver, Proc. Eng., The Fluor Corp., Ltd., Box 7030, East L. A. Station, Los Angeles 22, Calif.

DEADLINE—Oct. 26, 1955

Annual—Boston, Mass., Hotel Statler, Dec. 9-12, 1956.

TECHNICAL PROGRAM CHAIRMAN: W. C. Rousseau, Proc. & Sales Eng., Badger Mfg. Co., 230 Bent St., Cambridge 41, Mass.

DEADLINE—August 9, 1956

UNSCHEDULED

Centrifugation

CHAIRMAN: J. O. Maloney, Chairman, Dept. Chem. Eng., Univ. of Kansas, Lawrence, Kan.

Extraction of Hydrocarbons for Chemical Use from Pipe Line Gases

CHAIRMAN: E. E. Frye, J. F. Pritchard & Co., 210 W. 10th, Kansas City 5, Mo.

Bubble Mechanics

CHAIRMAN: Prof. R. C. Kintner, Dept. Chem. Eng., Ill. Inst. of Tech., 3300 Federal St., Chicago 16, Ill.

Chairman, A.I.Ch.E. Program Committee

George Armistead, Jr., George Armistead & Co.,

1200 18th St., N.W., Washington, D. C.

Assistant Chairman

L. J. Coulthurst, Foster Wheeler Corp.

165 Broadway, New York 6, N. Y.

AUTHOR INFORMATION

Submitting Papers

Members and nonmembers of the A.I.Ch.E. who wish to present papers at scheduled meetings of the Institute should follow the following procedure.

First, write to the Secretary of the A.I.Ch.E., Mr. S. L. Tyler, American Institute of Chemical Engineers, 120 East 41st Street, New York, requesting three copies of the form "Proposal to Present a Paper Before the American Institute of Chemical Engineers." Complete these forms and send one copy to the Technical Program Chairman of the meeting for which the paper is intended, one copy to the Assistant Chairman of the A.I.Ch.E., Program Committee, address at the top of this page, and one copy to the Editor of Chemical Engineering Progress, Mr. F. J. Van Antwerpen, 120 East 41st Street, New York.

If you wish to present the paper at a particular symposium, request 4 copies of the proposal sending a copy to the Chairman of the symposium.

Before Writing the Paper

Before beginning to write your paper you should obtain from the meeting Chairman, or from the office of the Secretary of the A.I.Ch.E., at 120 East 41st St., New York, a copy of the A.I.Ch.E. Guide to Authors, and Guide to Speakers. These cover the essentials required for submission of papers to the A.I.Ch.E. or its magazines.

Copies of Manuscript

Five copies of each manuscript must be prepared. For meetings, one should be sent to the Chairman of the symposium, and one to the Technical Program Chairman of the meeting at which the symposium is scheduled. If no symposium is involved, the two copies should be sent to the Technical Program Chairman. The other copies should be sent to the Editor's office since manuscripts are automatically considered for publication in Chemical Engineering Progress, or the symposium series of Chemical Engineering Progress, but presentation at a meeting is no guarantee that they will be accepted.

News of the Field
FROM LOCAL SECTIONS

Akron. In "Ramifications of the Atomic Energy Program in Southern Ohio," A. J. Gracia, general manager, Goodyear Atomic Corp., Portsmouth, Ohio, covered mostly those problems introduced by moving in a predominantly agricultural community with so large an industrial program as the new atomic energy plant in that area. His remarks were a feature of the Section's last meeting for the year (May 7), at which the official color movies of the 1952 H-bomb test on Eugelib Island were shown.

On this triple-barrel program, first the temporary chairman of the Akron group of chemical engineers in 1937—just prior to receiving its charter from the National Institute—H. L. Trumbull, gave a talk entitled "Launching of the Local Section of A.I.Ch.E." In this he related some interesting doings of the meetings held in those early days and this led up to another feature of the program—awarding a certificate of life-time membership in the Akron Section to another charter member, Maurice A. Knight, Sr., president of M. A. Knight Co. An example of Mr. Knight's generosity has been the entertainment of the Section at its annual picnic in September for the past several years at his estate on North Portage Path in Akron.

Paul A. Lindstedt, chairman of Akron Section, makes presentation to Mr. Knight.

—H. L. NICHOLSON

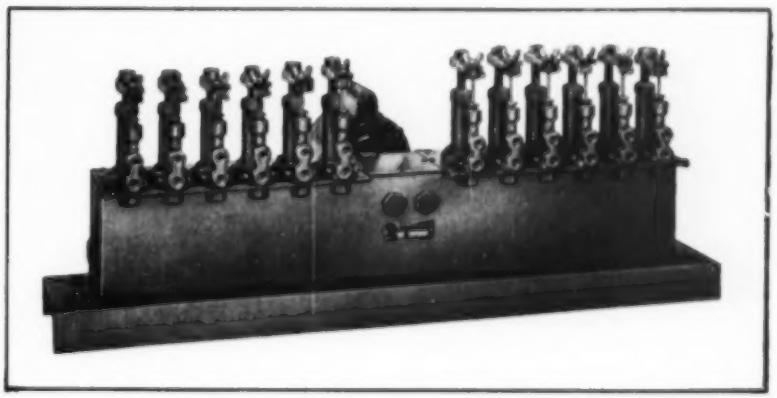
Atlanta. Technical aspects of the operation of the Tennessee Copper Co. as related by Bob Burns, production manager, featured the fourth meeting of this Section, which was held on May 22. The meeting was a combination field trip-business-session dinner and was

(*Continued on page 73*)

Got a Chemical Feeding Problem?

MANZEL
can help you solve it!

The flexibility of Manzel Chemical Feeders permits the accurate feeding of many different chemicals simultaneously — at a rate from a few drops to 60 gallons per hour. Adjustment is easy and the simple Manzel design insures trouble free operation. Where special problems call for specially engineered installations, the Manzel organization has the ability to deliver.



It's Manzel, too, for Force Feed Lubricators

Where efficient, economical operation depends on pressure lubrication — in exact amounts — accurately timed — Manzel Force Feed Lubricators are your answer.

Manzel

DIVISION OF FRONTIER INDUSTRIES, Inc.
315 BABCOCK STREET, BUFFALO 10, NEW YORK

SOMETHING'S FISHY IN BOSTON!

A. W. Fisher, Jr. Arthur D. Little, Inc., Cambridge, Massachusetts

During its twenty-odd years of existence, the Ichthyologists of Boston have been variously the source of delight and despair, envy and scorn, agreement and disagreement and, to some extent, misunderstanding within A.I.Ch.E. We believe we have something here and it is my hope to explain briefly this somewhat independent offspring of the Institute.

The Ichthyologists came into existence in 1931 and the original members were the committee for the Annual Meeting which was held in Boston that year. The name originated from the fact that at the Friday meetings of the committee, both before and after the convention, the discussion invariably got around to who would eat fish and what kind. It was carried to the point that one of the members exclaimed, "You guys are not chemical engineers, you're ichthyologists." The name has stuck ever since, and the spirit of the founders has also been retained in the names of the officers and other unusual traditions, including the continuation of Friday meetings. That this group was not entirely a frivolous one is indicated by the names of some of its past and present members, including Gus Esselen, Frank Curtis, Oz Bezanson, John Healy, Tom Sherwood, Walt Whitman, Ken Bell, John Blake, and many others who have more than demonstrated their ability as leaders in the chemical engineering profession.

Officers of the Ichthyologists are the Kingfish, the Mackerel, the Smelt and the Shark, the latter naturally being the Treasurer. The proper salutation by a member addressing a meeting is "Fellow Fish." Other traditions, including the sacred insignia of the Kingfish which Ken Bell created, have helped to carry on this spirit of good fellowship and fun. In the early days the section was quite small; most meetings numbered from ten to fifteen people. However, it grew gradually with the result that an invitation was proffered by the national organization for the Ichthyologists to become the Boston Section. The group agreed, providing their own bylaws, written largely by Tom Sherwood, would be accepted by Council. Some typical sections follow.

Article I—Name
This organization shall be known secretly as the Republican and New Deal Athletic and Debating Society, and to outsiders as the Ichthyologists of Boston.

Article II—Meetings
Section 1—Meetings shall be held occasionally.
Section 2—The order of business shall be varied so as not to get monotonous.

Article VII—Year
The fiscal year shall start Oct. 7, which is Harvey Skinner's birthday.

Article X—Records
No records of proceedings shall be kept.

Article XII—Quorum
A quorum shall consist of those present and in their right mind.

With these bylaws to set the general tone, it was difficult for the group, even as it grew, to take itself too seriously. Shortly after World War II—the membership had obviously become too large for the loose organization which had previously sufficed—it became necessary to reorganize and rewrite the bylaws. The group which did this, however, understood what the founders had been driving at, and was able to achieve considerable success in adding some real objectives and providing for the needs of a local section without destroying the old spirit. The original bylaws must always be appended unchanged whenever a new set is published. A copy of the present bylaws was recently sent to every local section through the Institute Sections Committee.

The major purposes of the regular meetings are good fellowship among the chemical engineers of eastern Massachusetts, and professional broadening and inspiration. The former is served by the informal atmosphere and the social hour before each dinner meeting. The final meeting each spring is a social event, usually a dance where wives can get acquainted too. To cover the second objective, a standing rule is in effect that the speaker of the evening must not discuss chemical engineering as such. However, speakers have been carefully selected from local people who have a story to tell of professional interest to the chemical engineer in his broader outlook on his business and his community. One of the early postwar meetings heard the immediate past Governor of the State of Massachusetts speak on "The Engineer and Politics." Some speakers have discussed financial subjects such as how to start a business of your own, how to finance new or existing corporations, how to make money on the stock market, etc. Others with valuable ideas to contribute have addressed the meetings; among them are psychologists, lawyers, union leaders, personnel men, and historians. Attendance has grown steadily and, in spite of a mailing list of only about 350 and an active dues-paying group of not more than 150, often members and guests present at a meeting number 100 or more.

Each spring the commercial subsidiary of the Ichthyologists "Enterprise Unlimited—Industrial Activity in New England Since 1620," holds its annual meeting. A handpicked "Board of Directors" from local business hears the "Director of Research" and his men present all aspects of a broad problem in chemical technology and then discusses the pros and cons. Last year it was an analysis of the possibilities for an ammonia plant in New England. This spring the subject was atomic power for New England. In the nature of symposia these get-togethers offer a real opportunity both for participation and learning. They are put on by an independent committee since the Kingfish is "too busy with the regular program."

The present Ichthyologists still maintain an independent and distinctive local section and feel that they have a real program with ideas which have been proved worth while. Whether this approach will work anywhere else, they don't know, but they like it!

(Continued from page 71)

held at Copperhill, Tenn., where fifty members and visitors were the guests of the company. Four groups were formed for three and one-half hour tours of the mines, roasting and sintering operations, acid plant, and flotation plant. Those choosing the mine tour were furnished hard hats and lights. Old clothes were the uniform of the day for all tours. At the business session, Noel R. Maleady reported on vocational guidance and requested those who had received questionnaires to fill in and return them to him. "Dinner dress" was the same old clothes worn on the tours, but otherwise the dinner, compliments of the Tennessee Copper Co., couldn't have been distinguished from the most formal and sumptuous banquet.

—H. H. Sneath and F. E. Rowe

Baton Rouge. His experiences in the small chemical industry, and the pros and cons of such a venture were highlighted in an address by T. E. Wannamaker, T. E. Wannamaker, Inc., Orangeburg, S. C., at the June 10 meeting of this Section. Mr. Wannamaker founded the Wannamaker Chemical Co. on a $12,000 shoestring to produce one product, *p*-phenylenediamine. —T. C. Landrum

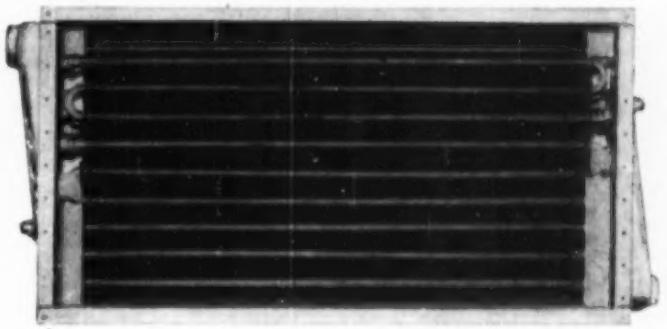
(Boston). Ichthyologists Annual Ladies' Night was held on May 22 under the chairmanship of Larry Michel, Godfrey L. Cabot, Inc. Approximately 100 couples enjoyed the evening dinner-dance at the Walker Memorial in Cambridge. Ken Bell presided over a brief ceremony for the installation of the new 1954-55 season officers, whose names were given in C.E.P., June, 1954, page 76. —A. G. Smith

Central Ohio. How different gems and the differences between synthetic and natural gems are distinguished, and how gems are evaluated were topics discussed by Bill Argo, Registered Jeweler of the American Gem Society, before thirty members and guests who attended the May 25 meeting held at Hoffman Gardens, Columbus. Titled "Gems and Gemology," the talk was supplemented by a number of unusual and interesting displays (not samples), which were passed around the audience.

—E. E. Smith

Central Oklahoma. At the second annual social meeting held May 20, thirty husbands and wives enjoyed a barbecue dinner in one of Oklahoma City's parks,

We Make Extended-Surface HEAT EXCHANGERS Exclusively!



The pioneer in the field, Aerofin has concentrated on one thing, *and one thing only* — highly efficient, easily installed, easily maintained extended-surface heat exchangers. Aerofin's design, research, engineering and production experience and facilities are unequalled anywhere.

For High Efficiency, Easy Installation, Low Maintenance and Servicing Costs . . .

ASK THE AEROFIN MAN

Aerofin is sold only by manufacturers of fan system apparatus. List on request.

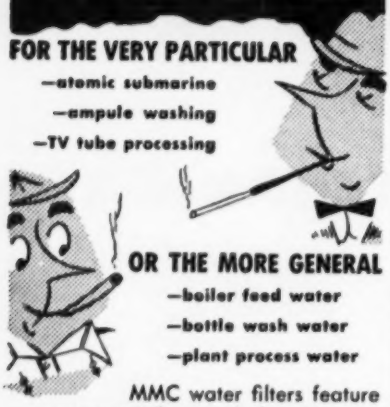
AEROFIN CORPORATION

101 Greenway Ave.
Syracuse 1, New York

WATER FILTERS

FOR THE VERY PARTICULAR

—atomic submarine
—ampule washing
—TV tube processing



OR THE MORE GENERAL

—boiler feed water
—bottle wash water
—plant process water

MMC water filters feature porous stainless steel elements, perfect medium support for diatomaceous earth, guaranteed cleanable corrosion resistant construction, 0.2 to 1000 gpm service

Request Brochure No.

Another filtration engineering service of

Micro Metallic Corporation

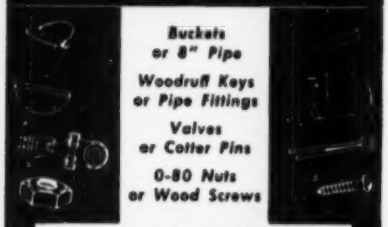
75-J Sea Cliff Ave. PALL Glen Cove, N. Y.

The Pall Filtration Companies

Micro Metallic Corporation | Porous Plastic Filter Co. | Aircraft Porous Media, Inc.

SCHNITZER

The Most Varied Line of STAINLESS STEEL PRODUCTS under one roof!



Buckets or 8" Pipe
Woodruff Keys or Pipe Fittings
Valves or Cotter Pins
0-80 Nuts or Wood Screws

Balls, bolts, chain, dairy fittings, dippers, faucets, floats, gauge glasses, hinges, hose clamps, machine screws, pipe, pails, pumps, rivets, scour cloths, sight flow glasses, taper pins, tubing, tubing fittings, ware, welding fittings, wheel brushes and many others.

Types 302—303—304—316—347 Carpenter 20

Catalogue on Request

SCHNITZER ALLOY PRODUCTS COMPANY

3543 Pine Street

Elizabeth, New Jersey

News of the Field

FROM LOCAL SECTIONS

followed by a most entertaining display of magic put on by Professor Lyle Albright of the University of Oklahoma, who performs semiprofessionally. Because of the unseasonable chill in the air the most welcome feature of the picnic was the roaring blaze in the fireplace. —E. E. WOODWARD

Cleveland. The pattern and problems of sales were discussed by W. H. McConnell, vice-president-sales, Diamond Alkali Co., following an inspection trip of the chlorine, soda ash, and power-producing facilities of the company's Painesville Works on May 25. The forty-odd visiting members and guests were escorted in groups of nine on the tours, which lasted two and one-half hours. —D. J. PORTER

Detroit. The final event of the season was in the form of a plant trip on June 12 to the Polymer Corp., Ltd., in Sarnia, Ontario, with approximately forty in attendance. The tour took about three hours plus a half hour for lunch at the midpoint.

—D. W. ANDERSON

New York. How marketing factors affect plant and equipment design was covered by Lawrence Flett, director of new products division, National Aniline Division, Allied Chemical and Dye Corp. at the May 27 dinner meeting of the New York Section. Approximately eighty people were in attendance. He showed how plant size, location, materials of construction, etc., are dependent on such factors as required product quality, market potential, and availability of raw materials.

The following officers were chosen for 1954 and 1955:

Chairman—R. F. Shaffer, Pratt Institute
Vice-Chairman—C. H. Chilton, McGraw-Hill Publishing Co.
Secretary—S. B. Adler, The M. W. Kellogg Co.
Treasurer—J. F. Lawrence, The Lawrence Co.

Other members of the Executive Committee are: F. B. White, Foster Wheeler Corp., the local section president during the past year, and Thomas M. Jackson, Jr., Johns Manville Sales Corp. —A. JONNARD

Northeastern New York. The position of the chemical engineer in industry was the subject of an address by C. G. Kirkbride, President of A.I.Ch.E., at the May 20 joint meetings of this Section and the R.P.I. Student Section. He stressed the fact that the engineer is primarily responsible for the economy which is in existence today and that the engineer of the future will have to take a greater interest in the economic and political life of the United States. He further emphasized that reliability of judgment is the most important characteristic for success. An animated discussion period followed.

—F. C. STEINER

Northern California. Covering such distillation calculation tools as "K" values from fugacities or activity of coefficients for equilibrium, enthalpy compilations for heat balances, temperature-pressure exponents for compression and expansion developed by a combination of fundamental properties, thermodynamics, etc., Wayne C. Edmister, supervisor of engineering research, Process Engineering Division, California Research Corp., addressed the June 21 meeting. The meeting was held at the Engineers' Club in San Francisco.

—SAN FRANCISCO ENGINEER

Ohio Valley. "Postwar Developments in Synthetic Fibers," and "A Correlation between Natural Convection and Forced Convection Coefficients of Heat Transfer on the Same Basis" were the two papers presented on Annual Student Night by Donald Case and Ronald Hoke respectively, when by custom the program is given by students from the University of Cincinnati. After the dinner meeting of this Section held at the Engineering Society of Cincinnati headquarters in Cincinnati, the following officers for the next year were elected.

President .....Stan Baechle
Vice-President .....Robert St. John
Secretary .....Sven Englund
Treasurer .....Alex Davidson

—N. M. MORLEY

Pittsburgh. Solar energy is a dilute power source. With these words H. C. Hottel, professor of fuel engineering at M.I.T., began his address on solar energy before the eighth monthly and annual meeting of this Section at the Sheraton Hotel. Types of collection apparatus for solar energy can be divided into photosynthesis, photoelectric, and thermal, he continued. In closing, Hottel pointed out that the photoelectric and photochemical methods must await knowledge gained through basic research before they reach any prominence. Food from algae is a possibility in the future, but power from this source appears to be uneconomical for some time to come. The use of flat plate collectors may be important in home heating within the next decade.

—MORRISSEY AND BLACK

Rhode Island. Statistics on the extent of the crime problem and methods of the F. B. I. that are used to counter this threat were covered in an address titled "Work of the F.B.I." by Special Agent J. A. Oxley before the May 20 meeting of this Section. He spoke at great length on the problem of bogus checks and told stories of cases that the F.B.I. and local police in cooperation had solved in this field.

At this meeting the following men were elected for the 1954-55 year.

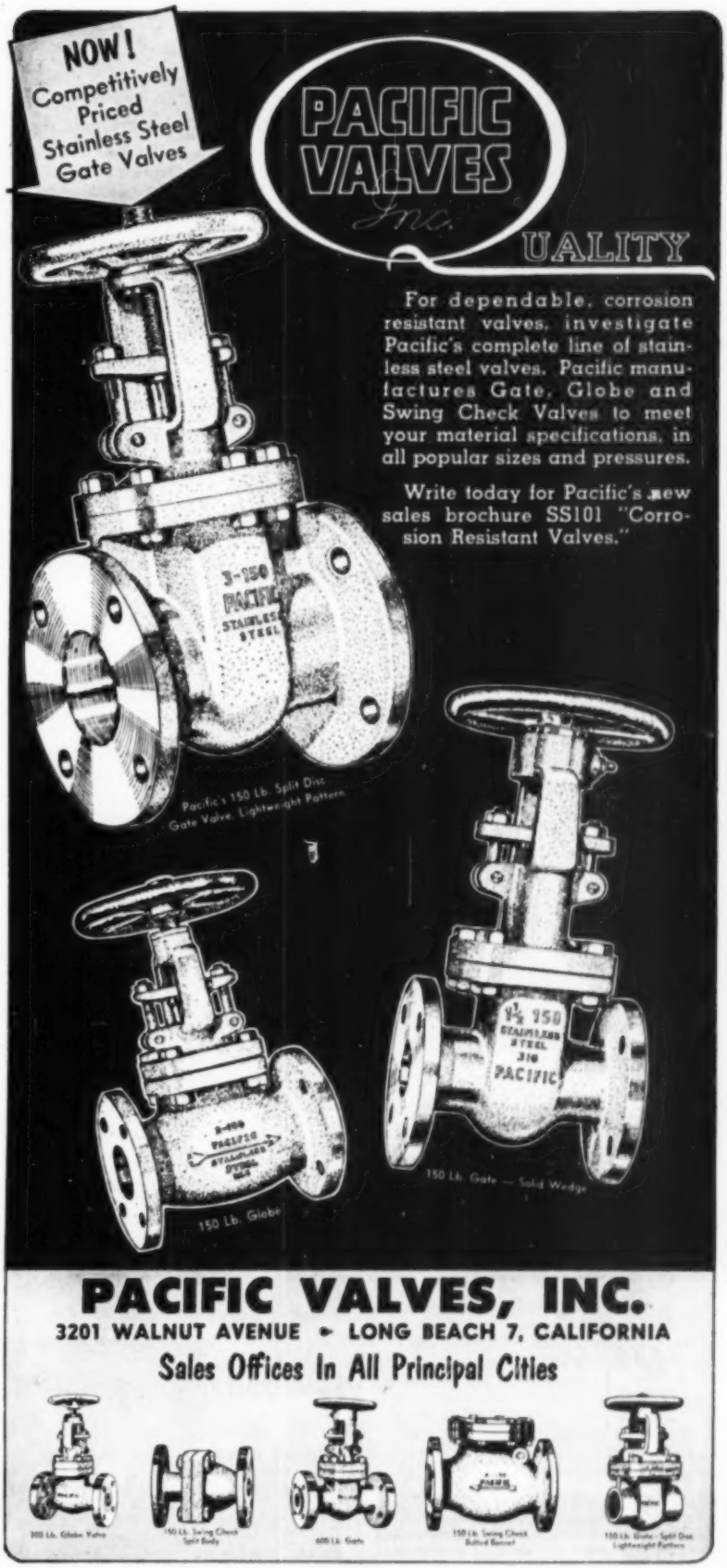
Vice-Chairman.....Morton I. Port
Sec'y-Treasurer....Andrew Melynchuk
Exec. Comm'n.....A. Ralph Thompson

A member moved that "the secretary cast a unanimous ballot for Dr. W. George Parks as chairman," and the motion was seconded, voted, and passed. Dr. Parks thanked the members for the honor bestowed upon him and pledged that he and the officers would do their best to make the 1954-55 year an enjoyable one. —M. I. PORT

Rocky Mountain. Claiming that unity was a hard thing to define and stressing that the expected benefits from a unified organization varied greatly, specifically with the age of the individual, Stephen L. Tyler, Executive Secretary, A.I. Ch.E., addressed this Section at a dinner meeting in Denver on May 25. He traced the development of a unified engineering group from the formation of American Engineering Council to the formation of the Engineers Joint Council. Mr. Tyler did not confine himself to the subject of Engineering Unity but also touched on other Institute problems and interests. His informative talk closed this Section's doors until fall when the lead-off meeting will be held at Glenwood Springs. —R. M. BERRY

Southern California. "Process Design for Maximum Controllability" is the title of a paper scheduled to be presented by J. G. Ziegler, Taylor Instrument Companies, at the July 20 meeting of this Section. He will refer to the control characteristics of various typical processes and types of process equipment. Further he will show where their inherent weaknesses lie from the standpoint of automatic control; and he will go on to explain how simple modifications can often be made to improve them immeasurably in this respect. Mr. Ziegler is well known among instrument engineers for his papers on automatic control. Swally's Key Club in Los Angeles will be the place of the meeting. —F. Y. STAATS

Watch for the August issue—a story on the New York Section Annual Symposium—Program of papers will be given.


NOW!
Competitively Priced Stainless Steel Gate Valves
PACIFIC VALVES Inc.
UALITY
For dependable, corrosion resistant valves, investigate Pacific's complete line of stainless steel valves. Pacific manufactures Gate, Globe and Swing Check Valves to meet your material specifications, in all popular sizes and pressures.
Write today for Pacific's new sales brochure SS101 "Corrosion Resistant Valves."
Pacific's 150 Lb. Split Disc Gate Valve, Lightweight Pattern
150 Lb. Globe
150 Lb. Gate — Solid Wedge
PACIFIC VALVES, INC.
3201 WALNUT AVENUE • LONG BEACH 7, CALIFORNIA
Sales Offices In All Principal Cities

from TEST GRINDING to TONNAGE CRUSHING

There's a
Custom-Built AMERICAN CRUSHER

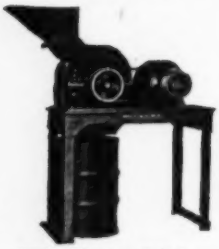
From small laboratory mills to high tonnage mills, American Crushers—with *built-to-the-job efficiency*—are famous for long-time service at *lowest possible cost.*

WRITE FOR LITERATURE ON THE COMPLETE AMERICAN LINE

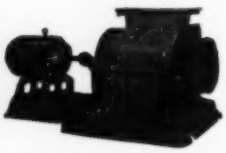
"AC" Ring Mill with patented Shredder Rings—to 500 TPH

"30 Series" Hammermill —to 100 TPH

Laboratory Mill—testing . . . exacting small scale operations



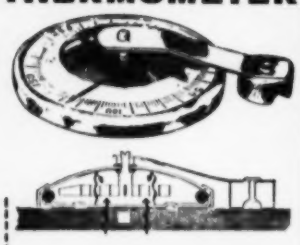
"KC" Plastics Grinder—to 450 lbs. per hour



"24 Series" Ring or Hammer Crushers to 50 TPH

American PULVERIZER COMPANY
Originators and Manufacturers of Ring Crushers and Pulverizers
2115 Macklind Ave., St. Louis 10, Mo.

PANDUX
SURFACE TEMPERATURE THERMOMETER



...for accurately measuring the temperature of any surface.

Pandux gives linear thermal readings ±2° full-scale accuracy. Unit sealed. Affixes to surfaces with magnet or silicone grease. 2" in diameter. Fully guaranteed.

Check model(s) wanted

$6.75 Complete with magnet clamp and 1/2 oz. of silicone grease

MODEL NO.
☐ 309F: −50°F to 250°F
☐ 309C: −50°C to 110°C
☐ 310F: 0°F to 300°F
☐ 310C: −10°C to 150°C
☐ 311F: 70°F to 370°F
☐ 311C: 20°C to 180°C

ORDER NOW — Clip this ad and staple to your letterhead and send to Dept. C-74.

PACIFIC TRANSDUCER CORP.
11921 W Pico Blvd. Los Angeles 64, California

• Your order will be filled through your nearest dealer

ONE-PIECE SPUN TRAYS
for the PACKAGED
Turbo-Dryer
CONTINUOUS, VERTICAL, TRANSFER TYPE

for **SENSITIVE PRODUCTS**

High efficiency
Low maintenance
Easily accessible for quick cleaning

also **suitable for COOLING**

Write for Bulletin!

Agents in Principal Cities
WYSSMONT COMPANY
42-05E 27th Street (Bridge Plaza South) Long Island City 1, New York

PEOPLE

J. T. Cox

W. W. Weinrich

John T. Cox, Jr., and W. Whitney Weinrich have announced their association as consulting chemical engineers, with offices at 1518 "K" Street, N.W., Washington, D. C. Mr. Cox has long been established in Washington with practice in rubber, chemicals, and petrochemicals. Mr. Weinrich goes from the petroleum industry where he was manager of process engineering department, Catalytic Construction Co. In addition to petroleum and chemicals Mr. Weinrich has done extensive work in the design and development of atomic energy processes.

M. C. Throdahl of Nitro, W. Va., has been named assistant director of the development department, organic chemicals division, Monsanto Chemical Co. Throdahl, who has been section manager of rubber chemicals in the development department, will temporarily continue this responsibility in his new position in St. Louis. He joined Monsanto in 1941. In 1945 he was appointed a group leader in the company's research department at Nitro and in 1952 he joined the development department as section manager of rubber chemicals.

E. O. Ohsol was recently appointed director of research, Pittsburgh Coke & Chemical Co., Pittsburgh, Pa. Dr. Ohsol will continue to direct the company's engineering activities, providing a close integration of research and process development programs. He has been director of chemical engineering since joining the company in 1952. Previously he was associated with General Electric as manager of new products laboratory, and before that with the Esso Research Center of Standard Oil and Development Co.

John E. Powers recently joined the process engineering department, Shell Development Co. Emeryville Research Center, as an engineer. Powers received his Ph.D. from the University of California.

Joseph A. Neubauer, technical director for Columbia-Southern Chemical Corp., is now a member of the company's board of directors. He joined the company in 1933 as a chemical engineer in the process department at the Barberton plant, later serving as development engineer and assistant production superintendent. When the firm's large chlorine, caustic soda plant was being built at Natrium, W. Va., he was in charge of the chemical engineering design and when the plant went into production he was made works manager. In 1946 he was appointed technical adviser to Columbia-Southern and has served as technical director during the past five years.

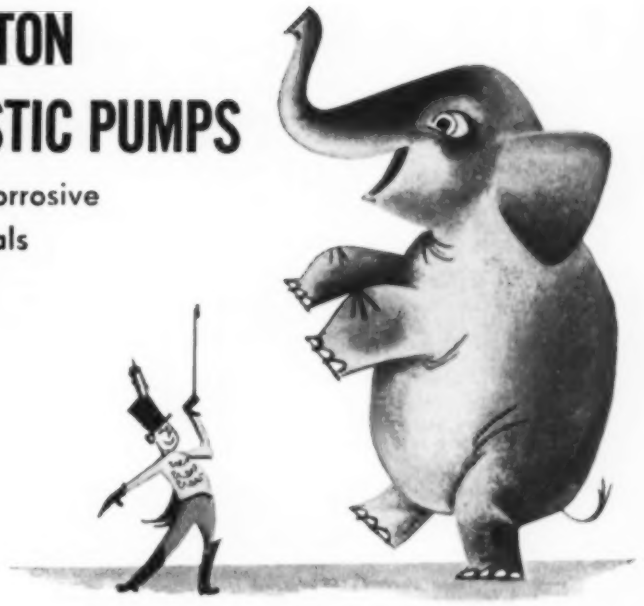
Appointment of **Richard M. Lawrence** as director of business research for Wyandotte Chemicals Corp., Wyandotte, Mich., producer of alkali and organic industrial chemicals, was announced, effective July 1. His headquarters will be in new research center at Wyandotte.

Mr. Lawrence has been senior market analyst in general development department of Monsanto Chemical Co. since 1947. Prior to that he was chemical market analyst for Atlas Powder Co. and chemical expert for the U.S. Tariff Commission. Currently he is serving as president of the St. Louis Chapter of American Marketing Association and is a member of the industry advisory committee, U. S. Bureau of Census. Mr. Lawrence was chairman of the symposium on chemical market research for the A.I.Ch.E. Atlanta meeting.

Frank P. Vance has been appointed chief, operations evaluation group, atomic energy division, research and development department, Phillips Petroleum Co. at the National Reactor Testing Station near Idaho Falls, Idaho. Mr. Vance has been with Phillips since May, 1946, and in the atomic energy division since 1951. Previous assignments in the division have included responsibility for fissionable material accountability and control of technical information, and supervision of a liaison group providing engineering service to irradiation projects at the Materials Testing Reactor. Currently he is responsible for surveillance by means of statistical analysis and process evaluation of all operations of the Phillips A.E.C. contract, comprising the Idaho Chemical Processing Plant, the Materials Testing Reactor, and auxiliary services.

VANTON PLASTIC PUMPS

tame corrosive chemicals



Flex-i-liner **PUMPS** are becoming industry's standard for those difficult to handle corrosive solutions and abrasive slurries, such as HCL, HF, NaOH, H_2SO_4, distilled H_2O, $FeCl_3$, HCOOH, and $Al_2(SO4)_3$, because their unique design eliminates stuffing boxes, shaft seals, gaskets and check valves.

NO METAL IN CONTACT—The only parts in contact with the fluid being pumped are the outer surface of the durable precision molded flexible liner and the inner surface of the pump body block, both of which are available in a wide selection of corrosion and contamination resistant materials.

FLEX-I-LINERS:
● Pure gum rubber ● Natural Rubber ● Neoprene
● Hycar ● Buna N ● Silicone ● Vinyl ● Compar

BODY BLOCKS:
● Polyethylene ● Bakelite ● Buna N
● Lucite ● Unplasticized PVC
● Available in stainless steel for special applications.

Flex-i-liner
Plastic Pump

NO STUFFING BOX—Elimination of stuffing boxes, packing glands and shaft seals, avoids the possibility of external leakage and prevents contamination of the transferred liquid by oil or grease.

SELF PRIMING—Vanton self priming plastic pumps give immediate operation in any position.

GET THE FACTS—Write for bulletin "VP" and the full story of Vanton plastic pumps

OUR CORROSION RESISTANT PRODUCTS FOR FLUID HANDLING include a complete line of Buna N and Natural Hard Rubber centrifugal pumps, valves, pipe and fittings. Bulletin BHR on request.

vpe

VANTON
PUMP & EQUIPMENT CORP.
EMPIRE STATE BUILDING • NEW YORK 1, N. Y.

ARTISAN DESIGNS MANUFACTURES

- Autoclaves
- Condensers
- Heat Exchangers
- Distillation Equipment
- Evaporators
- Jacketed Kettles
- Mixers
- Pipe
- Reactors
- Tanks

• *Pilot Plants* • *Complete Plants*

Telephone or write. Engineering Representatives throughout the United States

ARTISAN METAL PRODUCTS, INC.

Telephone:
Waltham 5-6800

73 Pond Street
Waltham 54, Mass.

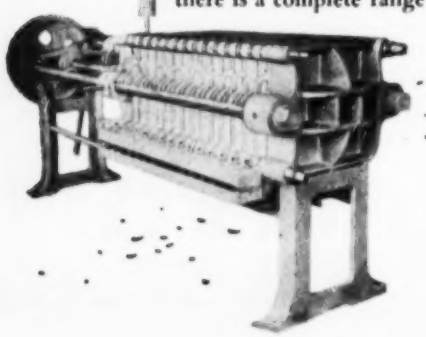
Vacuum rectifying column—with automatic air-operated control—designed to operate either batch or continuous.

SPERRY HAS THE ANSWERS

—Whatever Your Filtration Problems May Be . . .

During a half century of designing filter presses for America's manufacturing companies, Sperry has solved nearly every known type of industrial filtration problem. Sperry Filter Presses are flexible in size and design . . . there is a complete range of filter bases . . . and a choice of six different closing devices.

Send for the Sperry Filter Press catalog and you'll see why Sperry can solve *your* filtration problems efficiently and economically.



D. R. SPERRY & CO.

BATAVIA, ILLINOIS

FILTRATION ENGINEERS FOR MORE THAN 60 YEARS

Eastern Sales Representative:
GEORGE S. TARBOX
808 Nepperhan Avenue,
Yonkers 3, N. Y. Yonkers 5-8400

Western Sales Representative:
B. M. PILHASHY
833 Merchants Exchange Bldg.
San Francisco 4, California
DO 2-0375

C. G. Clear, assistant to the vice-president, development and engineering division, Emeryville Research Center, Shell Development Co., became the assistant manager of the head office, Technological department, Shell Oil Co., New York, July 1. Clear, a graduate of the University of California with a Ph.D. degree in chemistry, joined Shell in 1937.

Ian D. Patterson, synthetic rubber coordinator, Goodyear Tire & Rubber Co., will address the Third Rubber Technology Conference in London sponsored by The Institution of the Rubber Industry. The title of his talk is "How Synthetic Rubbers Affect You." Patterson joined Goodyear as a chemical engineer and tire compounder in Akron in 1921.

James Harrington Boyd, a consultant in the economic and process phases of petrochemicals, synthetic rubber, and plastics received the honorary degree of D.Sc. at the 126th commencement of Kenyon College, Gambier, Ohio. Dr. Boyd is also a visiting professor in chemical engineering at Columbia University and a director of Dasher Rubber and Chemical Co.

A leave of absence has been granted **John R. Durland,** plant manager of the John F. Queeny plant, Monsanto Chemical Co., to permit him to attend the fall session of the Advanced Management Program at the Harvard University Graduate School of Business Administration. Dr. Durland joined Monsanto in 1939.

D. B. Benedict

The appointment of **Donald B. Benedict** as works manager of Carbide & Carbon Chemicals Co., division of Union Carbide and Carbon Corp., was recently announced. He received his B.S. degree (1932) and his M.S. degree in chemical engineering (1933) from the University of Michigan. Mr. Benedict joined Carbide as a technical assistant in the chlorhydrin department at the South Charleston, W. Va., plant in 1933, becoming assistant superintendent of chemicals and resins in 1940 and general superintendent of the plant in 1952. He was transferred to the New York office in 1953, when he became assistant works manager.

William Engs, formerly manager of manufacturing, agricultural chemicals division, American Cyanamid Co., has been appointed assistant to the president of Stauffer Chemical Co., its subsidiaries and associated companies. He joined American Cyanamid in 1941 as technical co-ordinator of various war projects for the Chemical Construction Corp. subsidiary, becoming director of Cyanamid's chemical engineering division of Stamford Laboratories, and, later, manager of operations of North American Cyanamid Ltd.

B. R. Sarchet, manager of the Kobuta, Pa., chemical plant of Koppers Co., Inc., since 1951, is now the assistant sales manager of the chemical division, with headquarters in Pittsburgh. Replacing Mr. Sarchet at Kobuta is **Frank R. Garner,** who has been assistant plant manager since 1949.

Sarchet graduated from Ohio State University and received his M.S. degree in chemical engineering at the University of Delaware. He joined the Koppers engineering and construction division in 1941 and has held various positions in that division, in the research department, and in the chemical division. He became manager of the chemical division's Oil City, Pa., plant in 1947 and of its Kubuta plant in 1951.

Mr. Garner was graduated from Cooper Union with a B.S. degree in chemical engineering. He joined Koppers in 1942 and has worked at the Kobuta plant since then, being variously superintendent of styrene, director of process engineering and assistant plant manager.

Alex Katona, formerly of Cleveland, Ohio, has joined the research and development department in the pilot plant group, Hooker Electrochemical Co., Niagara Falls, N. Y. Dr. Katona received his B.S., M.S., and doctor's degrees in chemical engineering from Case Institute of Technology. From 1949 to 1951 he was an assistant in the department of chemistry and chemical engineering at Case.

J. J. MacFarland has been appointed to the newly created post of assistant to the general manager of the plastics division of Celanese Corporation of America. Mr. MacFarland joined the company in 1947 and shortly thereafter was made manager of the product development department of the chemical division.

Finds "Our Paul O. Abbé Mixers GIVE WELL BALANCED PERFORMANCE"

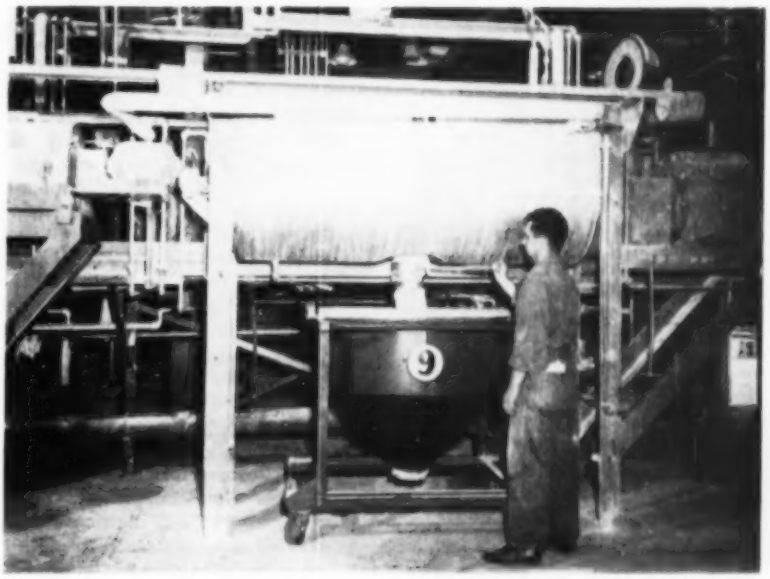


Photo courtesy Hercules Powder Company

A well-known manufacturer had to mix cellulose acetate with various colorants.

They wanted:

1. **To get homogeneous mix.**
2. **To eliminate any possibility of contamination or discoloration from one batch to the next.**
3. **To obtain maximum size of batch.**
4. **To be able to mix a wide range of formulations without lumping.**

Their Paul O. Abbé Mixers have met every need.

"What we were looking for was a versatile mixer — one that met every one of our requirements to a high degree," they state.

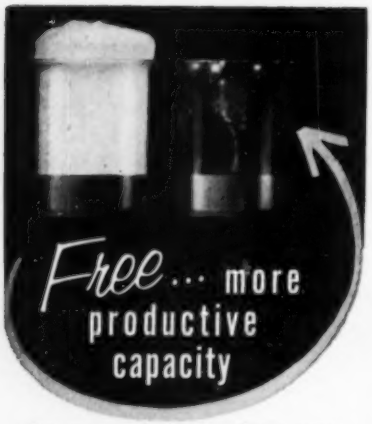
"Our Paul O. Abbé Mixers we find give well-balanced service. They are versatile. They rank high in meeting our requirements."

You, too, may find Paul O. Abbé Mixers help you solve your mixing problems.

Write today for illustrative folder.

PAUL O. ABBÉ

271 Center Avenue **Little Falls, New Jersey**



Get more production from your present processing equipment. Increase capacity by eliminating space-wasting foam with Dow Corning silicone defoamers. Here are some typical examples:

- ✔ standard molasses processing load increased from 18 to 24 tons!
- ✔ yield on textile vat dyes doubled!
- ✔ in processing food, vacuum concentration capacity increased 60%!
- ✔ proposed $2,000,000 expansion of processing plant made unnecessary by efficient foam control!

Dow Corning Antifoam A Compound and Antifoam AF Emulsion are the most versatile and economical defoamers on the market. Effective at remarkably low concentrations, they pay for themselves time and again in more complete use of process equipment and shorter processing time, and in the elimination of waste and fire hazards. Both defoamers are tasteless, odorless and physiologically harmless.

For more efficient foam control . . .

Use DOW CORNING ANTIFOAM A or DOW CORNING ANTIFOAM AF EMULSION

send for FREE SAMPLE

Dow Corning Corporation, Dept. CS-19
Midland, Michigan
Please send me data and a free sample of
☐ Dow Corning Antifoam A
or ☐ Dow Corning Antifoam AF Emulsion

NAME_____
COMPANY_____
ADDRESS_____
CITY_____ ZONE____ STATE____

Paul Kandell is associated with the American Potash & Chemical Corp., Los Angeles, Calif., as a chief engineer. A graduate of New York University with a B.Ch.E. degree in 1943, Kandell has been affiliated with Carbide and Carbon Chemicals Corp., Oak Ridge, Tenn.; The Intercontinent Corp., New York; Chemical Construction Corp., New York; and Bechtel International Corp., Los Angeles, Calif., and London, England.

S. Jackson Wommark, Jr., has recently been appointed an assistant for division research and also manager of chemical process development of Olin Industries, Inc. Formerly section chief of the research and development department film division, Mr. Wommack's responsibilities include film, paper, forest products, and electrical divisions of the company. He joined the Ecusta Paper Corp., an Olin subsidiary, as a development superintendent in 1950. Previously he was with Monsanto Chemical Co. for nine years as an analyst, assistant production supervisor, development engineer and project engineer.

D. J. Porter, formerly assistant to the director of research, is now assistant general manager and division research director of the recently formed chlorinated products division, Diamond Alkali Co. He will be responsible for all research work of that division except agricultural chemicals. **J. J. Lukes,** formerly development section manager, was named research manager. He will assist Dr. Porter in carrying out divisional research responsibilities and functions.

John A. Sherred was recently named director of research development, plastics division, Monsanto Chemical Co., St. Louis. He joined Monsanto in the Texas City, Tex. plant in 1947 and since 1952 has been in charge of development functions in the research department at that site.

T. S. Carswell, vice-president in charge of the biochemicals division, has been elected a director of Commercial Solvents Corp., New York. He joined the company in 1946 after thirty years' experience in the chemical industry. Until January of this year when he assumed his present duties, he served as vice-president in charge of the research and development department.

ENGINEERING PHYSICS

#5 of a Series

Our facilities include a completely staffed Engineering Physics Section. We are able to translate some of the newer developments in physics to assist in the solution of engineering problems.

SHOCK and VIBRATION—including studies of these forces and methods of reduction and elimination.

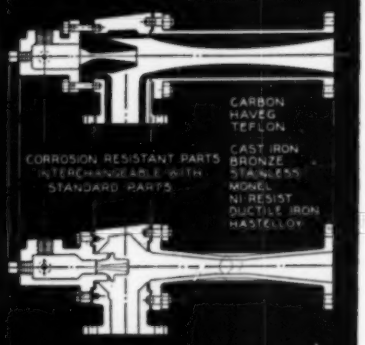
ULTRASONICS including engineering application to such diverse uses as cleaning, homogenizing, dispersing and sterilization.

RADIOACTIVITY including tracer elements in chemical engineering unit operations; and in sterilization, particularly foods.

WE WELCOME inquiries and the opportunity to propose studies involving physics.

FOSTER D. SNELL INC.
29 WEST 15th ST. NEW YORK 11, N.Y. — WA 4-8800

STEAM JET
EJECTORS
CONDENSERS
VACUUM
EQUIPMENT



THE JET-VAC CORP.
73 POND STREET
WALTHAM, MASS.

Melvin C. Molstad, director of the school of chemical engineering at the University of Pennsylvania, will be Fulbright lecturer at the Norwegian Institute of Technology at Trondheim for the 1954-55 school year. Dr. Molstad was associated with the Fixed Nitrogen Research Laboratory, Department of Agriculture, as chemical engineer before he went to Yale University as instructor and assistant professor. Later he served Du Pont in the ammonia department.

H. W. Dahlberg, Jr., has been appointed assistant to Howard F. Roderick, vice-president in charge of phosphate chemicals division, International Minerals & Chemical Corp. Mr. Dahlberg has been a member of International's research division since 1945, serving first as a research chemical engineer in Florida, and later in Chicago where he served for five years as assistant to Paul D. V. Manning, vice-president in charge of the corporation's research division. Most recently Mr. Dahlberg has been research supervisor in charge of the technical economic department and the research library.

The appointment of **James A. Pollock** as factory manager of the new Ashtabula chemical plant of The General Tire & Rubber Co. has been announced. With General since 1943, he served first at the government-owned synthetic plant at Baytown, Tex., which is operated by the company, and later at the Akron headquarters. Previously, he was with United Engineers & Constructors, Inc., Philadelphia, as a design engineer.

George B. Stanton, Jr. is now technical sales representative of the Rubber and Asbestos Corp., Bloomfield, N. J. Mr. Stanton was formerly chief chemist of the Arvey Corp., Jersey City, N. J.,

Ernest F. Johnson has been promoted to associate professor of chemical engineering at Princeton University, effective July 1. Dr. Johnson received his B.S. degree from Lehigh University and his Ph.D. from the University of Pennsylvania. Prior to going to Princeton in 1948, he was with the Barrett division of the Allied Chemical and Dye Corp. and the thermodynamic research laboratory of the University of Pennsylvania.

(Continued on page 83)

Corrosion-Resistant Mortars for Acid- and Alkali-Proof Masonry in Floors, Tanks, Sewers, Towers, etc.

DELRAC FURANE CEMENT

Resistant to acids, alkalies and solvents, Delrac Furane Resin Cement sets quickly by internal chemical reaction. Safely used at temperatures up to 375° F. Black in color.

DELRAC POLYESTER CEMENT

Delrac Polyester Resin Cement resists most acid solutions, including oxidizing acids, mild alkalies and many solvents. Used at temperatures up to 250° F. White in color.

For Delrac specifications send details of your problem

DELRAC CORP. 134 Mill St., Watertown, New York

Resins, Corrosion-Resistant Cements and Coatings, Concrete Admixtures, Protective Tape Pipe Coatings

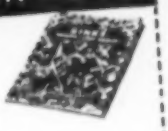
for chemical spraying, cooling, humidifying, dehydrating, and hundreds of other applications.

You'll get the right nozzles quicker by calling Binks...manufacturers of one of the most complete nozzle selections ever produced.

You'll have a wide range of spray patterns, sizes, capacities from which to choose...with nozzles cast or machined from any standard or special corrosion-resistant metals. Send for comprehensive catalog.

Binks Manufacturing Company
3114-32 Carroll Ave., Chicago 12, Ill.

MAIL COUPON NOW!



Binks Manufacturing Co.
3114-32 Carroll Ave.,
Chicago 12, Ill.

O.K. Binks, send me your Spray Nozzle Catalog...

Name_____

Company_____

Address_____

City_____ Zone____ State_____

CLASSIFIED SECTION

Address Replies to Box Number Care of CHEMICAL ENGINEERING PROGRESS

SITUATIONS OPEN

PHYSICAL METALLURGIST

Excellent opportunity open to a man who is qualified for, and interested in, development work in the field of applied nonferrous metallurgy. This work will be related to the operations of a processor of metal used in the A.E.C. program.

Applicants should have had advanced training at a recognized school and about five to ten years' experience in foundry or metal forming activities. A well-rounded background in physical metallurgy would be desirable. Also they should be eligible for security clearance by the A.E.C.

Please submit complete résumé of personal data, education, previous experience, salary received, and references. All replies will be treated in confidence. Box 2-7.

CHEMICAL ENGINEER

Major petroleum company has attractive process design position available. Experience in unit operations desirable. Chicago suburb. Replies confidential. Box 1-7.

SALES ENGINEER — Must have technical ability, degree in chemical engineering, and knowledge of filtration based, to a large extent, on actual experience in the chemical processing field. Desire a man between 30 and 40, who is sincerely interested in permanent career in sales engineering. Attractive base salary plus commission. Location —New England States. Please send complete résumé to Box 3-7.

HEAT TRANSFER

Graduate engineer with experience in rating tubular heat transfer equipment for oil refining and chemical processing plants. Some process experience would be desirable but not necessary. Submit résumé in first letter.

DOWNINGTOWN IRON WORKS, INC.
Downingtown, Pennsylvania

ENGINEER WANTED FOR RESEARCH IN FRACTIONATION — Duties will include planning the program, correlating data and writing reports. Salary open. Fractionation Research, Inc., 1000 S. Fremont Avenue, Alhambra, California.

EXPERIENCED ENGINEERS WANTED

Air Products, Incorporated, has openings for outstanding, capable engineers with three to eight years of experience in each of its process, estimating, project and development departments. Good scholastic record and good personality essential. The process, project and development positions require experience in or related to those positions. Experience in design and fabrication of complex liquid containers especially valuable in the project engineer opening. The estimating position to be filled by an experienced estimator who enjoys that work and has made contributions in that position. Starting salary commensurate with experience. Excellent opportunity for advancement in this fast-growing medium-sized chemical-equipment engineering and manufacturing company.

Reply to: AIR PRODUCTS, INC.
Personnel Department
P. O. Box 538
Allentown, Pennsylvania

SENIOR EQUIPMENT ENGINEER

Permanent position now available in an East Coast engineering and construction organization with an international reputation in the oil and chemical industries.

The job requirements include a degree in mechanical, chemical or electrical engineering, and eight years' experience in the chemical or petroleum industries. Five of these years must have been in mechanical equipment. Also desired is advanced technical knowledge in design and development of centrifugal and reciprocating machines, and packed units used in the industry and in power plant auxiliaries.

The man selected will be required to perform analyses of equipment selection and application problems; to solve complex problems in dynamic vibration and corrosion in petroleum and chemical service; and to consult on development of special equipment.

The salary is high and there is an unusually liberal employee benefit program including executive insurance and a retirement plan. Traveling and moving expenses will be paid.

Please submit complete details of background and experience and include initial salary requirements.

BOX #391, ROOM 1201, 230 WEST 41ST ST., NEW YORK 36, N. Y.

SITUATIONS WANTED

A.I.Ch.E. Members

EXPERIENCED CHEMICAL ENGINEER

Ph.D., P.E. Ten years in foods or in fields servicing foods — development, engineering, and coordination. Age 37. Desire change. Will relocate. Box 4-7.

CHEMICAL-MECHANICAL ENGINEER—Degrees, Dresden and Karlsruhe. Associate member A.I.Ch.E., M.E.I.C., P. E. Lecturer at McGill University. Fifteen years' experience as plant engineer and assistant manager in heavy industrial and chemical plants, process and design. French, German, some Spanish and Swedish. Single. Box 5-7.

TECHNICAL DIRECTOR

Ph.D., licensed chemical engineer, employed; twenty years' experience. Proven ability in administration, creative thinking and profitable commercial developments. Sixty patents: petroleum, petrochemical, inorganic processes. Box 8-7.

CHEMICAL ENGINEER—M.S. in Ch.E., N.Y. professional engineer. Capable of organizing and directing a process engineering group engaged in development or design. Age 32. Desire Eastern or Southern location. Box 9-7.

DIRECTIONS FOR USE OF CLASSIFIED SECTION

Advertisements in the Classified Section of Chemical Engineering Progress are payable in advance at 15c a word, with a minimum of four lines accepted. Box number counts as two words. Advertisements average about six words a line. Members of the American Institute of Chemical Engineers in good standing are allowed one six-line Situation Wanted insertion (about 36 words) free of charge a year. Members may enter more than one insertion at half rates. Prospective employers and employees in using the Classified Section of Chemical Engineering Progress agree that all communications will be acknowledged; the service is made available on that condition. Boxed advertisements are available at $15 a column inch. Size of type may be specified by advertiser. Answers to advertisements should be addressed to the box number, Classified Section, Chemical Engineering Progress, 120 East 41st Street, New York 17, N. Y. Telephone ORegon 9-1560. Advertisements for this section should be in the editorial offices the 15th of the month preceding publication.

CHEMICAL ENGINEER—Age 27. B.S. 1949. Five years of diversified experience in pilot plant engineering research and development. Prefer south central New Jersey location. Box 10-7.

EXECUTIVE MANAGEMENT ENGINEER—Ten years' experience. B.S.Ch.E. Pilot plant operations, plant design, economic evaluations, cost estimates, project coordination. Broad administrative experience. Wide variety of engineering details. Desire staff position. Eastern U. S. preferred. Box 11-7.

CHEMICAL ENGINEER—B.S. 1941. Thirteen years' experience in economic evaluation, process design, and operation of petrochemical and nitrogenous fertilizer plants. Desire position in small organization with incentive program. Present salary $10,000 annually. Box 12-7.

CHEMICAL ENGINEER—B.S. in Ch.E. 1951. Age 26, married, veteran. Experience: 2½ years in semiworks and pilot plant. Desire position in pilot plant or similar work. Available in October. Box 13-7.

CHEMICAL ENGINEER—B.Ch.E. 1947. P.E. Age 35, married, veteran. Seven years' experience pilot plant operation, research and development, plant design and operation; two years' experience laboratory technician. Desire position offering opportunity and responsibility. Northern New Jersey—metropolitan area preferred. Box 14-7.

NEW PRODUCT DEVELOPMENT—Chemical engineer, Ph.D., age 36, with extensive experience in research, development, business, and corporation management. Want administrative or executive work with company seeking to diversify its products. Box 15-7.

CHEMICAL ENGINEER—B.S. Age 32, married, family. 7½ years' varied experience in pilot plant supervision, second line production supervision, plant engineering and technical service work. Seeking responsible supervisory position. Will relocate. Box 16-7.

PEOPLE

(*Continued from page* 81)

John W. Shier, production manager, Acheson Colloids Co., Port Huron, Mich., was recently named president of the Port Huron Industrial Management Club. He is active in the Engineering Society of Detroit. Before joining the Acheson organization in 1949 as plant engineer, Mr. Shier was employed as a chemical engineer by the Heyden Chemical Co., Detroit. Recently he was elected chairman of the Detroit Section of A.I.Ch.E.

Lindal L. Mark and **James C. Linak** have recently joined the staff of Whiting Research Laboratories of Standard Oil Co. (Ind.). Mr. Mark obtained his master's degree in chemical engineering at Columbia University, and has recently been associated with the engineering center of that university.

Mr. Linak, who received his master's degree in chemical engineering at the University of Wisconsin, was recently associated with the Food Machinery and Chemical Corp.

Ronald A. Graham is now manager of contract research, research and development division, Wyandotte Chemicals Corp., Wyandotte, Mich. He joined the company as an engineer in the chemical engineering research department in 1947, transferred to contract research work in 1950 as project engineer, and in 1953 became assistant to the director.

Bruce Jones is now a vice-president of the Panhandle Oil Corp., Wichita Falls, Tex. Prior to his election as vice-president he was refinery manager of the plant at Wichita Falls, and he will continue in this capacity in his new post. Prior to joining the company in 1952 he was chief project engineer with the Votator Division of the Girdler Corp., Louisville, Ky., for about five years. Before joining the Girdler Corp. he had been with the Texas Co., serving in several technical capacities at Port Arthur, Houston and New York City.

Lester Mount, formerly assistant to the production manager, Shawinigan Resins Corp., Springfield, Mass., is now plant manager responsible for all production, maintenance and quality control activities. Mr. Mount has served the company as production supervisor from 1947 to 1951. After two years as project engineer with American Cyanamid he returned to Shawinigan in June, 1953. He holds a bachelor's and master's degree in chemical engineering from Princeton University.

Howard G. Vesper, vice-president of Standard Oil Company of California, is the new president of the Industrial Research Institute, Inc., New York. He is also president of Standard's subsidiary, the California Research Corp. Mr. Vesper, a graduate of California Institute of Technology, has been with Standard of California since 1922.

William Claus Behrmann recently received the Fulbright foreign study award for the 1954-55 academic year, from the University of Kansas. He is now studying for a master's degree in chemical engineering at the University of Kansas and will attend the Technological University in Delft, The Netherlands.

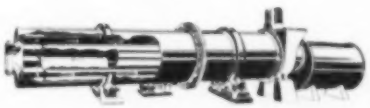
Kenneth M. Irey has recently become assistant vice-president of Heyden Chemical Corp., New York. He joined the company in 1949 and has been chemical production manager since 1953. Previously he served as assistant manager of Heyden's Garfield, N. J., plant. From 1939 to 1949 Mr. Irey was plant superintendent of the plastics plant, Monsanto Chemical Co., Springfield, Mass. He previously was associated with Resinox Corp. as plant superintendent and with Commercial Solvents Corp. as research chemist.

The appointment of **Henry Avery** as manager of the coal chemicals division, Pittsburgh Coke & Chemical Co., was recently announced. He has been manager of the plasticizer division of that company since 1951 when he joined the company, and will continue to carry these responsibilities as well as those of manager of the coal chemicals division.

Ruggles-Coles

DRYERS

KILNS & COOLERS



DOUBLE-SHELL
SEMI-DIRECT HEAT DRYERS

DOUBLE-SHELL
INDIRECT-HEAT DRYERS

SINGLE-SHELL DIRECT-HEAT
COUNTERFLOW DRYERS

STEAM TUBE
INDIRECT-HEAT DRYERS

SINGLE-SHELL DIRECT HEAT
PARALLEL-FLOW DRYERS

SINGLE-SHELL DIRECT HEAT
HOT AIR DRYERS

ROTARY COOLERS

ROTARY KILNS

Write for Bulletin 16-D-40

HARDINGE
COMPANY, INCORPORATED
YORK, PENNSYLVANIA · 240 Arch St. · Main Office and Works
New York · Toronto · Chicago · Hibbing · Houston · San Luis City · San Francisco

SHRIVER DIAPHRAGM PUMPS Pay Off!

in
- better efficiency
- less supervision
- less maintenance
- lower costs

for CORROSIVE • ABRASIVE VISCOUS • THICK • VALUABLE DELICATE OR HAZARDOUS MATERIALS

It pays to use this positive action, large volume, efficient pump on materials that clog and destroy conventional pumps. No packings, no leakage; easy to clean and maintain; low operating cost. Built of any material; pressures to 100 p.s.i. Rated capacity—1 to 90 g.p.m.

T. SHRIVER & COMPANY, INC. • 812 Hamilton St., Harrison, N. J.

Filter Presses • Filter Media • Diaphragm Pumps

Sales Representatives

The Merrill-Brase Co. 2792 Cypress St. Oakland 7, Calif

Process Eng. & Equipt. Co. 331 Thornton Ave. St. Louis 19, Mo.

The Watts Co. P. O. Box 8188 Houston, Tex.

Richardson Agencies, Ltd. Toronto, Ont. Montreal, Que.

HYDROCARBON PANAFLEX ...EP-1 PLASTICIZERS

A LOW COST PLASTICIZER OIL for Rubber Compounding

PROPERTIES
Low Specific Gravity — Dark Viscous Liquid
Extremely High Boiling

FOR
Improved Processing — Improved Electrical Characteristics
Minimum Effect on Cure
Extending Vulcanizates — Better Tear Resistance

EXCELLENT COMPATIBILITY WITH
GRS Rubbers—All Types — Buna N Type Rubbers
Neoprene Rubber

AVAILABILITY
Basic Producer — Tank Car or Drums
Warehouse Distribution

PAN AMERICAN CHEMICALS DIVISION
Pan American Refining Corp
122 EAST 42ND STREET • NEW YORK 17, N. Y.

Necrology

C. M. A. STINE DIES

Charles M. A. Stine, a leader in the research program of the Du Pont Co. and President of American Institute of Chemical Engineers (1947), died May 28. Dr. Stine was 71 years old.

When Dr. Stine retired in 1945 as a member of the company's executive committee and adviser on research and development, he had rounded out thirty-eight years of his professional life with Du Pont. Over this long period he covered many assignments—head of organic chemical work at Eastern Laboratory (1909-16); head of organic division, Wilmington office (1917-19); assistant director of chemical department (1919-24); chemical director of Du Pont Co. (1924-30); vice-president and director and member of executive committee (1930-46). During these years he had developed many processes and products in connection with high explosives, propellent powder, dyes, artificial leather, varnishes, and paints. For several years he was a consultant to Chemical Warfare Service. He served on the advisory committee on chemical engineering curriculum of Princeton University and has served in the same capacity at M.I.T.

For the Institute he had served as Director, Vice-President and President.

Abroad as well as in United States, Dr. Stine became one of the best known of industrial research directors. "For valuable work in applied chemistry" he was awarded the Perkin Medal in 1939 by the American Section of the Society of Chemical Industry.

A native of Connecticut, Dr. Stine received his Ph.D. degree from Johns Hopkins University. Since his retirement Dr. Stine had been a member of Du Pont's board of directors.

E. E. MARBAKER

Edward E. Marbaker, Distinguished Senior Fellow of Mellon Institute, died June 2, 1954. He received his B.S. (1910) and his Ph.D. (1914) from the University of Pennsylvania.

INDEX OF ADVERTISERS

	Page
A	
Abbé, Inc., Paul O.	79
Ace Glass, Inc.	6
Aerofin Corp.	73
Aldrich Pump Co.	16
American District Steam Co., Inc.	38
American Machine & Metals, Inc.	13
American Pulverizer Co.	76
Artisan Metal Products, Inc.	78
Autoclave Engineers, Inc.	19
B	
Badger Mfg. Co.	67
Barco Mfg. Co.	42
Bartlett & Snow Co., The C. O.	21
Barton Instrument Corp.	29
Binks Mfg. Co.	81
Black, Sivalls & Bryson, Inc.	27
Bowen Engineering, Inc.	59
Buflovak Equip. Div., Blaw-Knox Co.	17
C	
Carbide & Carbon Chemicals Co., A Division of Union Carbide and Carbon Corp.,	*Inside Front Cover*
Carboline Company	14
Chemical & Industrial Corp.	31
Chicago Bridge & Iron Co.	22
Condenser Service & Engineering Co.	52
Crane Company	12
Croll-Reynolds Co., Inc.	85
D	
Delrac Corporation	81
DeZurik Shower Co.	47
Dollinger Corp.	65
Dow Chemical Co.	53
Dow Corning Corporation	80
Duraloy Company	69
E	
Eimco Corporation	11
F	
Falls Industries, Inc.	46
Fischer & Porter Co.	18
Fluor Corp., Ltd.	54
G	
General American Transportation Corp.	326
Girdler Company, The	25
Great Lakes Carbon Corp., Electrode Division	51
Gump Company, B. F.	3
H	
Hamer Valves, Inc.	43
Hardinge Co., Inc.	83
Hilliard Corporation	24
I	
Ingersoll-Rand	23
International Nickel Co., Inc.	39
J	
Jet-Vac Corp., The	80
Johns-Manville	20
K	
Kinney Mfg. Div., The New York Air Brake Co.	41
L	
Lapp Insulator Co., Inc.	7
Lawrence Pumps, Inc.	68
Louisville Drying Machinery Unit, General American Transportation Corp.	326
M	
Manzel Division of Frontier Industries, Inc.	71
Marley Company, The	15
Metal Textile Corp.	24
Micro Metallic Corp.	74
Milton Roy Company	*Inside Back Cover*
Minneapolis-Honeywell Regulator Co.	8,9
Mixing Equipment Co., Inc.	*Back Cover*
N	
National Drying Machinery Co.	28
Niagara Filters Div.	13
P	
Pacific Transducer Corp.	76
Pacific Valves, Inc.	75
Pan American Chemicals Div., Pan American Refining Corp.	84
Pfaudler Company, The	49
Posey Iron Works, Inc.	32
R	
Rockwell Mfg. Co.	4,5
Rohm & Haas Co.	26
S	
Sandvik Steel, Inc.	30
Schnitzer Alloy Products Co.	74
Sharples Corp., The	63
Shriver & Co., Inc., T.	84
Snell, Inc., Foster D.	80
Sperry & Co., D. R.	78
Spraying Systems Co.	52
Struthers Wells Corp.	45
U	
Union Carbide & Carbon Corp., Carbide and Carbon Chemicals Co.,	*Inside Front Cover*
United States Gasket Co.	10
V	
Vanton Pump & Equipment Corp.	77
Vapor Recovery Systems Co.	48
W	
Whitlock Manufacturing Co.	50
Wyssmont Company	76

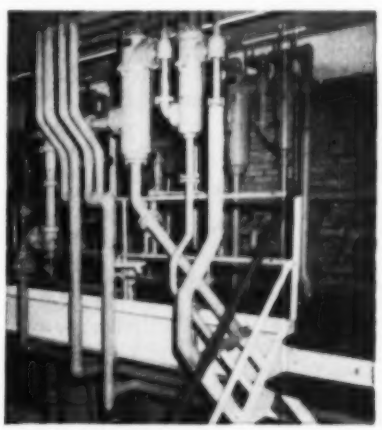
Advertising Offices

New York 17—Lansing T. Dupree, Adv. Mgr.; Paul A. Jolcuvar, Dist. Mgr.; 120 E. 41st St., Oregon 9-1560.

Chicago 11—Richard R. Quinn, Dist. Mgr., 612 North Michigan Ave., Room 507, Superior 7-0385.

Cleveland 15—Douglas H. Boynton, Dist. Mgr., 1836 Euclid Ave., Superior 1-3315.

Pasadena 1—Richard P. McKey, Dist. Mgr., 465 East Union St., Ryan 1-8779.



LET C-R EVACTORS help improve your health

This illustration shows two 4-stage Evactors in the plant of a leading manufacturer of vitamins and other pharmaceuticals. The same plant uses numerous other C-R Evactors of different types—as do the majority of manufacturers in this important field—for many different processes, including deodorizing, distilling, drying, refrigeration, etc. They are as simple as the valves that turn them on, yet maintain absolute pressures down to a small fraction of 1 m.m. absolute where steady, dependable vacuum is extremely important.

This steady, dependable vacuum is contributing to the improved health of our population by helping to supply purer and more potent vitamins, antibiotics and other pharmaceutical products. C-R also supplies Jet Mixers, Jet Heaters, Jet Absorbers, Jet Scrubbers, Jet Pumps, Jet Condensers and Barometric Condensers.

CROLL C R REYNOLDS

Croll-Reynolds CO., INC.

Main Office: 751 Central Avenue, Westfield, N. J.
New York Office: 17 John St., New York 38, N. Y.

CHILLVACTORS • STEAM JET EVACTORS • CONDENSING EQUIPMENT

A.I.Ch.E. NEWS AND NOTES

While this page usually stresses the actions of Council & Executive Committee . . . it recognizes the vitality & importance of member action both individually & collectively.

Meetings are prime examples of collective action.

Last month at Ann Arbor we saw the crystallization of many months of concerted action in a new phase of A.I.Ch.E. activity . . . a divisional meeting. Every meeting of A.I.Ch.E. is in the main similar . . . & these remarks are meant for every person who ever cooperated in an A.I.Ch.E. annual, national, divisional, or any other meeting . . . but the ability of a group which never worked together before to fit all the jig-saw pieces of activity into a smoothly operating meeting is nothing short of amazing. . . .

Committees are formed where no committee existed before . . . tasks are assigned . . . difficulties are foreseen & overcome . . . & the whole integrated with a program planned by an entirely separate group working under the National Program Committee.

Incidental but important is the value of such meetings to the local group . . .

Often from the inspiration that such a collective action creates comes a stronger local section . . . & even at company levels men find that such cooperation gives a rare opportunity to get to know fellow workers outside the daily environment. . . .

Strangely enough the above is the rule not the exception.

}; for a better & peppier local section, a national meeting.

An example of individual action & vitality is Jim Knudsen, editor of the Student Chapter News.

Jim is Associate Professor at Oregon State & for the past several years has accepted the responsibility for issuing four issues, every school year, of an A.I.Ch.E. student newspaper.

This activity, not known to most members, is of value to students & student chapter work.

Practically self-sufficient through student subscriptions, it requires only a minimum underwriting by the A.I.Ch.E.

One of Council's actions at Ann Arbor was to approve an expenditure to keep the Student Chapter News going next year. . . . For 1953-54 Knudsen reported to Council that 57 student chapters and 1,331 students subscribed.

Council passed a resolution expressing its loss in the death of Charles M. A. Stine. . . . He was the 28th President of the Institute.

A long hard look was also taken at publication policies & the general financial setup of the Institute. . . . Upshot was a re-affirmation of the decision made last December to begin A.I.Ch.E. Journal.

New Lapel Button is on way. Designs are being studied for the most pleasing arrangement. . . . Emblem for all new grades of membership (pin & watch charm) will be similar to Active member emblem. Newly designed lapel button will be small & inexpensive.

New amendments to the Constitution voted by Active membership passed easily; a tellers' report received by Council from W. G. Fogg & W. D. Kohlins showed proposal No. 1 passed with 2,016 in favor; 222 against . . . proposal No. 2--2,088 in favor; 150 against . . . proposal No. 3--2,112 in favor; 121 against.

This means that membership in the A.I.Ch.E. is now--Member, Associate member, Affiliate, & Student member. The new Associate member grade carries with it the privilege of nominating & voting for officers & directors. . . .

Affiliate requirement is the former Associate requirement as per Section 3d.

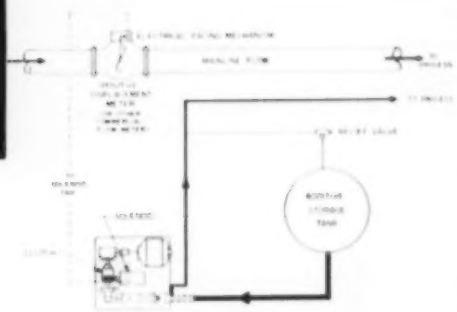
Proposal No. 2 provided for a nominating committee . . . plus nomination by petition from the membership. . . . The third proposal provides for authorization by Council of divisions.

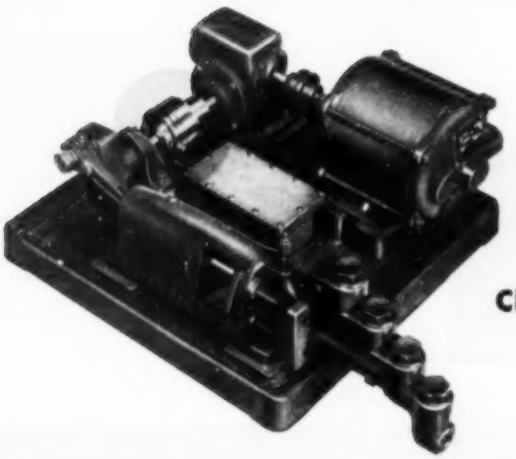
Changes in Membership also required change in dues & essentially the same dues structure now exists as was adopted by Council. Members, Associate members over 35, & Affiliates, dues of $18 . . . Associate members through age 35, dues of $12.

F.J.V.A.

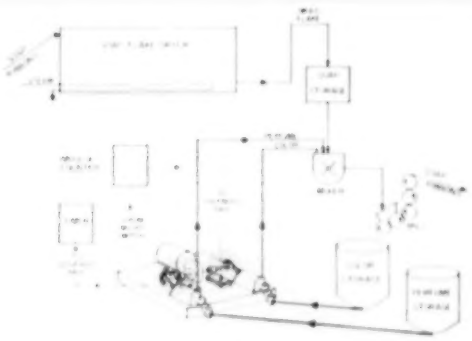
CONTROLLED VOLUME PUMPS ARE FLOW-CONTROL INSTRUMENTS

Positive displacement meter supplies signals proportional to main line flow causing Clutch-Actuated Pump to feed additive in exact ratio.





Latest Proportional Feed Techniques Use New Milton Roy Clutch-Actuated Flow Control Pumps



In simplified blending system, timer signal engages clutch to start stroke in first pump cylinder. Second clutch is actuated in proper ratio and total number of strokes is determined by Micro-switch and impulse counter.

● Accurate proportional feed . . . lower equipment costs . . . simpler installation . . . dependable operation . . . ALL are features of the newest Milton Roy development in flow control.

Designed primarily for process applications requiring inexpensive proportional feed, a Milton Roy Controlled Volume Pump and its constant speed motor are linked by a mechanical clutch in a single, compact assembly. Normally disengaged, the clutch is tripped by a solenoid upon electrical signal. The pump is then engaged for one complete suction-discharge cycle, and returned to its idling position while the motor continues to operate. Actuating signals may be supplied by a positive displacement meter or other flow meter for accurate proportional feed . . . by timer or other device where single stroke control is required. (See diagrams.)

Typical of the widespread applications of the new Clutch-Actuated Flow Control Pumps are the hundreds now in service in the Petroleum Industry's gasoline additive program. At pipeline distribution points these units are used to feed the additives in proportion to the gasoline flow. Pumps of high accuracy and rugged dependability are essential to the successful handling of these expensive additives.

Available in a wide range of models, capacities, and pressures, Milton Roy Clutch-Actuated Pumps are described fully in Bulletin 654. Write for a copy today.

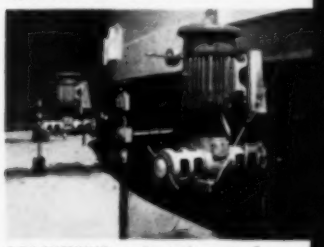
MILTON Roy COMPANY

Manufacturing Engineers 1379 E. MERMAID LANE • PHILA. 18, PA.

CONTROLLED VOLUME PUMPS AND AUTOMATIC CHEMICAL FEED SYSTEMS

IF THIS HAPPENS in your plant, will you have to junk the entire mixer because of ruined gears, bearings, and other parts? Mixer gears can wear out fast—unless they're protected from continuous buffeting of tank liquids, as well as from accidents. See below.

TOP ENTERING . . . turbine and paddle types. Sizes 1 to 500 HP.



SIDE ENTERING . . . for tanks up to 5 million gallons. 1 to 25 HP.

PORTABLE . . . electric or air driven. More than 30 models, ⅛ to 3 HP.

Even an *ACCIDENT* can't hurt the gears in this fluid mixer!

Specify LIGHTNIN Turbine or Paddle Mixers—and you'll never have to worry about shaft flexure being transmitted to the gears of the speed reducer.

Even if one of your operators accidentally drops a sack of solid material into the tank while the mixer is running, the shock load never gets back to the vital parts of the mixer drive.

Notice how the mixer shaft passes through the hollow quill of the speed reducer.

See how the mixer shaft and hollow quill are connected at only *one* point—by a flexible coupling. The coupling soaks up all the strain . . . isolates and protects the gearing.

That's one *big* reason why you get years and years of trouble-free, low-cost operation with LIGHTNIN Mixers.

There are many more good reasons why you cut costs with LIGHTNINS. Versatility, for example. The turbine-type LIGHTNIN Mixer you buy today can keep on serving you even if your process should change tomorrow. You can change the tank mounting, shaft, impellers, to meet new mixing requirements. You can even interchange *speeds*—by replacing two easy-to-get-at gears.

Finally, you're protected *process-wise* when you choose LIGHTNIN Mixers. Every LIGHTNIN is unconditionally guaranteed to do the mixing job right.

Your LIGHTNIN Mixer representative can tell you more about the long-term savings you can make with LIGHTNINS. You do not obligate yourself in any way—so why not give him a call right now.

1. SPEED REDUCER GEARS are protected in LIGHTNIN Mixers, by this hollow-quill construction. Driven by gears, the quill shaft turns on its own heavy-duty bearings.

2. MIXER SHAFT passes through the quill. Shaft turns on its own separate bearings. Shaft and quill are connected by a torsionally resilient flexible coupling (arrow).

3. SHAFT FLEX (greatly exaggerated here) can never reach gears, bearings, and other parts of speed reducer. All shock loads and stresses are absorbed by the flexible coupling.

- ☐ DH-50 Laboratory Mixers
- ☐ DH-51 Explosionproof Laboratory Mixers
- ☐ B-102 Top Entering Mixers (turbine and paddle types)
- ☐ B-103 Top Entering Mixers (propeller type)
- ☐ B-104 Side Entering Mixers
- ☐ B-105 Condensed Catalog (complete line)
- ☐ B-107 Mixing Data Sheet
- ☐ B-108 Portable Mixers (electric and air driven)

MIXING EQUIPMENT Co., Inc.

199-g Mt. Read Blvd., Rochester 11, N.Y.

In Canada: William & J. G. Greey, Ltd., 100 Miranda Avenue, Toronto 10, Ont.

Please send me, without obligation, catalogs checked at left.

Name _____ Title _____

Company _____

Address _____

City _____ Zone ____ State _____

"Lightnin Mixers"

GET THESE HELPFUL FACTS ON MIXING

LIGHTNIN Catalogs contain practical data on impeller selection; sizing; best type of vessel; installation and operating hints; full description of LIGHTNIN Mixers. Yours without obligation. Check and mail coupon today.

MIXCO fluid mixing specialists